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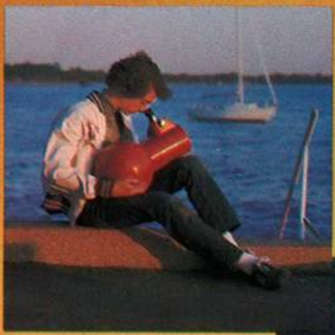
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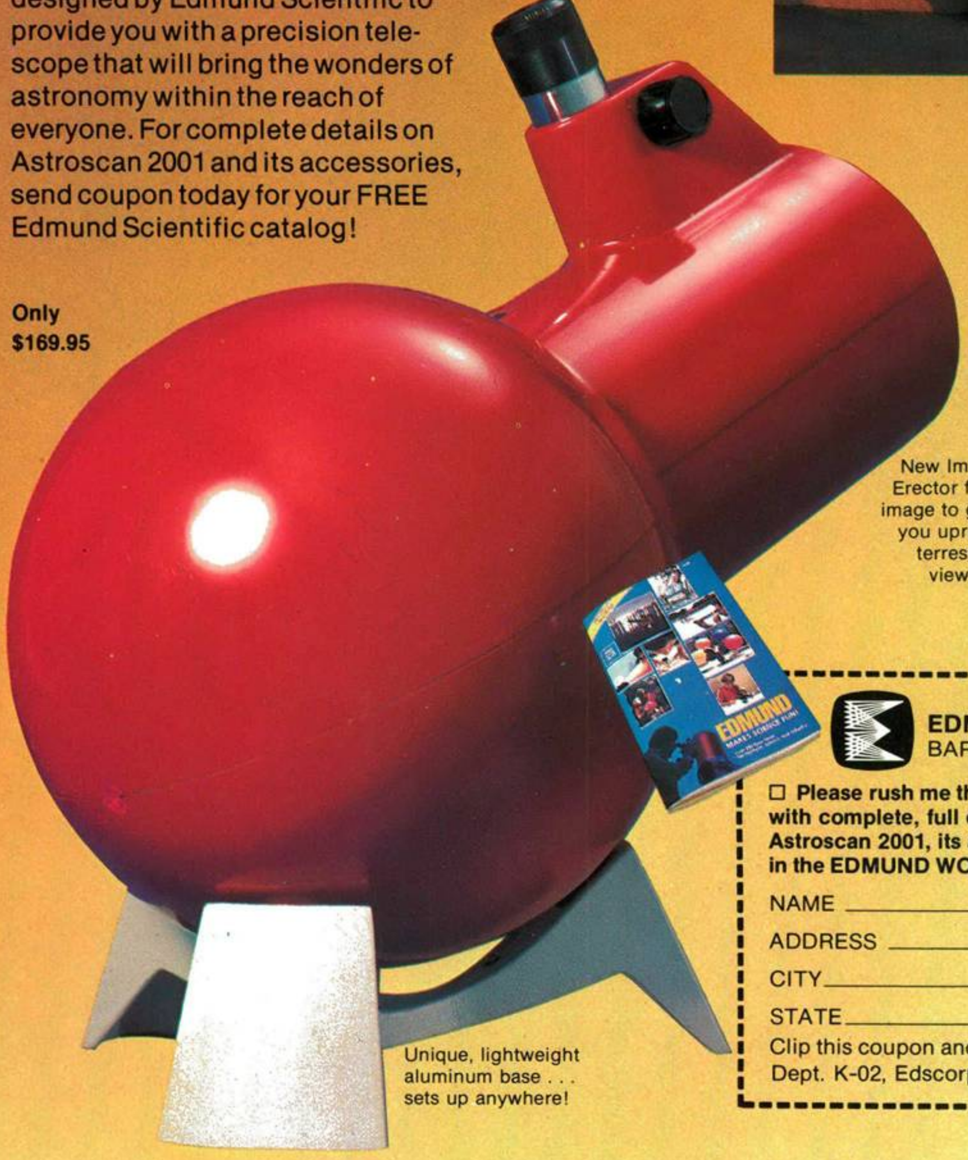

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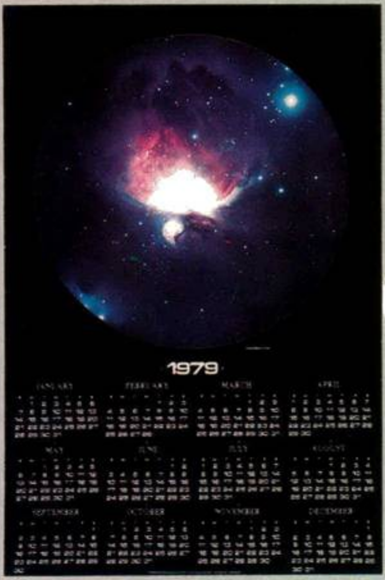

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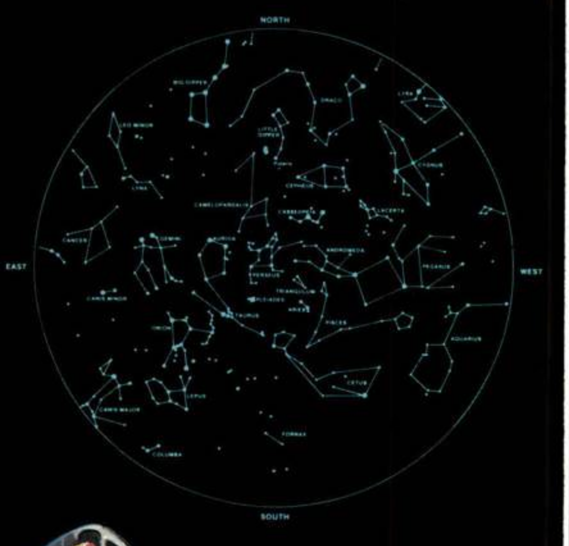

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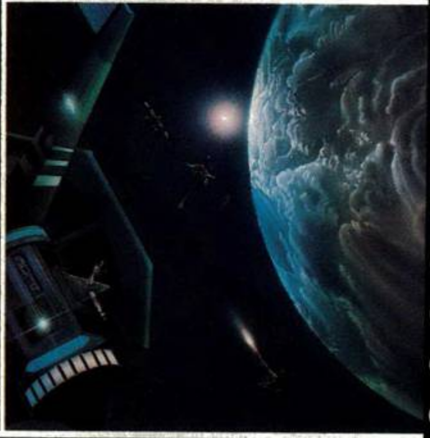

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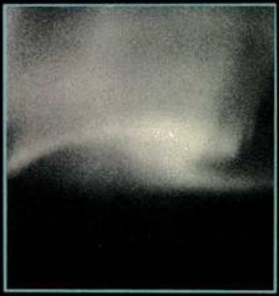

Cover

Golds, greens, magentas and yellows mingle in this brilliant auroral display seen in the skies over Edmonton, Alberta. Caused by charged particles from the sun, an aurora testifies not only to the awesome forces on the sun that spew out these energetic protons and electrons, but also to the marvel that they appear on Earth as delicate shimmering lights in the sky. This month ASTRONOMY tackles the vexing question of life in the universe: Is it really as common as we were led to think it might be several years ago? Then we move on to another intriguing problem: Did people in medieval England actually see the formation of a new lunar crater? This month's departments deal with observing and photographing open star clusters, and how you can build your own "sit-down" telescope — plus lots of book reviews and the monthly observing features. Photograph by David Roles.

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ARE WE THE ONLY INTELLIGENT LIFE IN OUR GALAXY?

by
Barry Parker

Have you ever looked into the sky on a dark clear night and wondered if there was life out there? If so, you're not alone; scientists around the world have been doing this for years, and now they're doing something about it. The depths of space are being probed by huge radio telescopes searching for telltale signs of an advanced civilization. But how likely is it that there is extraterrestrial life? Most astronomers would say the chances are excellent. Indeed, anyone who has read recent literature on the subject might think it is impossible that we are the only intelligent life in our galaxy.

Spinning serenely in the vast gulfs of intergalactic space, our galaxy (like the one seen here, NGC-2841) is home to uncounted billions of stars. Can it be that in this giant island universe of ours only one star shines down on a planet inhabited by intelligent beings? Perhaps. No one yet knows the answer to the question: Are we alone in the galaxy? Hale Observatories photograph.

But are we being too optimistic? We may be. Before we get into the details, however, let's look briefly at the history of our views on extraterrestrial life. What did early astronomers think? It may seem surprising, but they had no doubt that the solar system abounded with life. William Herschel, the foremost astronomer of the early 1800s, even believed that there was life on the sun! But like other early astronomers, all he could really do was speculate.

Then came the first evidence. Giovanni Schiaparelli, an Italian amateur astronomer, discovered lines on Mars which he called "canali". Were they canals — made by a race of Martians?

Many thought so, including Percival Lowell, a well-to-do naturalist, mystic and astronomer. Astronomy — Mars in particular — was his passion, and he had the resources to do something about it. In 1894 he set up an observatory at Flagstaff, Ariz., intending to prove that there was life on Mars (he also set it up to look for a planet beyond Neptune). Elaborate maps were drawn, and canals — even double canals — were shown connecting the polar regions and deserts. This, he believed, was the proof he needed. The canals were a sure sign of a dwindling water supply; the Martians had obviously built them to bring water from the poles to the parched deserts.

But as more and more discoveries were made the prospects for an intelligent civilization on Mars looked dimmer. Finally, with the first flight to Mars in 1965, came proof that there were no higher forms of life. But what about lower life forms — like bacteria? Everyone waited patiently as Viking I (and later Viking II) landed on Mars in 1976. But the news was no better; there also appeared to be no lower forms of life like bacteria. The proof is still not complete, but the prospects are dim.

Mars is our best candidate for extraterrestrial life inside the solar system; Venus is too hot. The gas giants do not have the proper conditions, and the other planets are either too hot or cold. Indeed, astronomers are now virtually certain that with the exception of Earth, there are no higher forms of life in our solar system, and there may not even be any lower forms of life.

But what about the vast regions beyond the planets? Is there life out there? This depends on many things, one of the most important of which is the origin of life. How did life arise and evolve on Earth? If we knew the answer to this, we'd be able to make a much better estimate of the probability of life among the stars.

A breakthrough came in 1953 when Harold Urey, of the University of Chicago, persuaded graduate student Stanley Miller to perform a critical experiment. (Perhaps we'd be more correct in saying that Miller persuaded Urey to let him do the experiment.) Miller attended a lecture by Urey on the origin of life, during which he pointed out that several people had tried to obtain the basic life molecules (or at least their components) using our present atmosphere and had failed. But the trick, he said, "is to use the atmosphere that was actually here at the time — the primitive atmosphere." This consisted of methane, ammonia and water vapor. Miller approached Urey after the lecture and asked if he could work under him on this experiment.

At first there was little interest, but when the significance of the experiment was finally realized, scientists around the world scurried to their labs in hopes of discovering one of the vital keys. Most of the components of the basic molecules of life (DNA, RNA and protein) were eventually obtained in simple experiments involving an energy source (such as an electric spark device) and a manmade imitation of the primitive atmosphere. But if life could arise spontaneously here on Earth, couldn't it also arise on a planet somewhere out among the stars, if all the conditions were right? It seemed reasonable. Astronomers were soon optimistic about the possibility of extraterrestrial life, even intelligent life, somewhere in our galaxy.

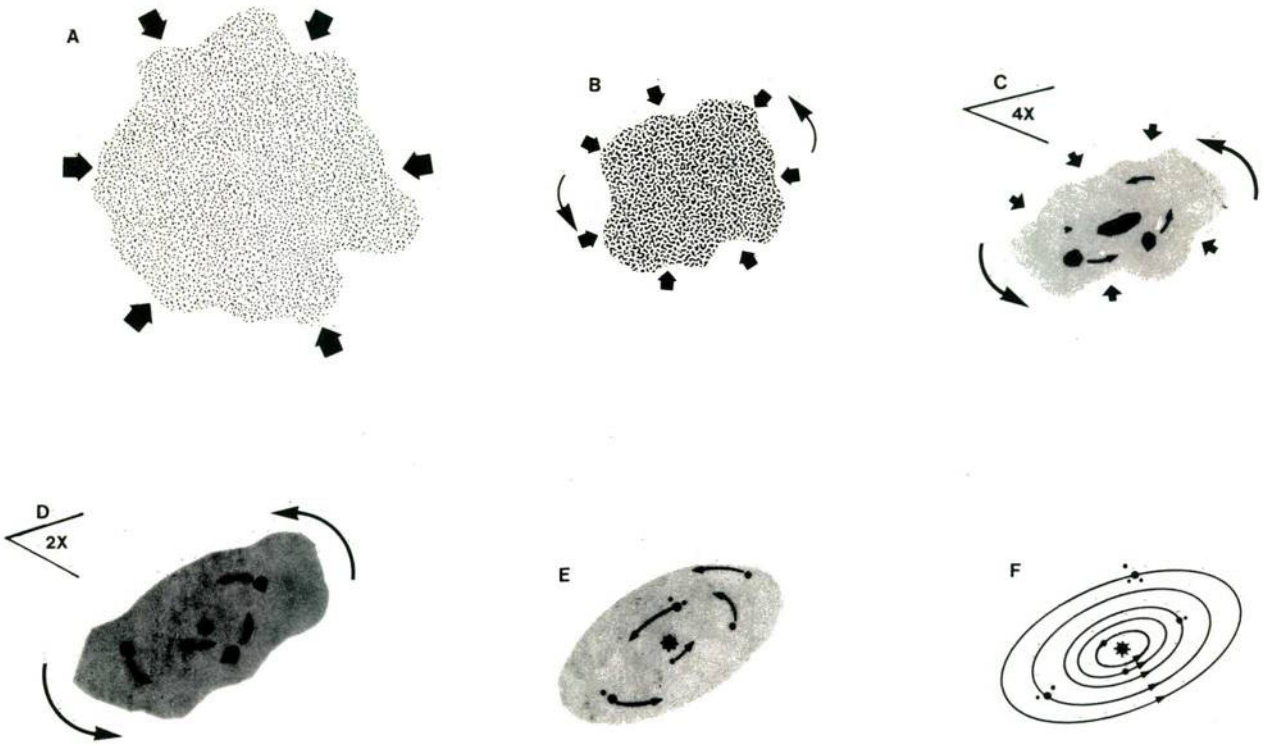
If this is indeed the case, is there any way we can estimate how many life supporting systems there are likely to be? And what about advanced civilizations that we could communicate with? Could we estimate how many of them there might be? There is a statistical procedure for calculating probable numbers for these things. But first we must establish the ground rules; we do this by making an assumption called the *assumption of mediocracy*. According to it, our solar system is typical of other solar systems in our galaxy. This does not imply that life will necessarily evolve on all planets that are similar to Earth; it only implies that we are average.

Now, let's see how statistics can help us. The approach we'll use is a slight variation of the one developed by Frank Drake, director of the Arecibo Radio Observatory in Puerto Rico, and Carl Sagan of Cornell University. Before we begin, however, we should point out that there are severe limitations in our method. It's difficult to gauge its accuracy (many of its flaws will be discussed later), and needless to say much of it is based on speculation, but it's the best we can do right now.

Our object is to estimate the probable number of advanced civilizations in our galaxy. We'll begin by asking how many of the 100 billion or so stars in it are suitable for life; by this, we mean that the star could support a life bearing planet. To be suitable, it would have to be stable over a long period of time — at least three billion years — and have a suitable ecosphere or life zone. The life zone is the region around a star where the temperatures are moderate and water is in the liquid state most of the time; this is, of course, where life is most likely to arise. In our solar system it extends from about the orbit of Venus out to that of Mars.

To examine this question further, let's go to the main sequence of the luminosity-temperature diagram (for the stars in our galaxy). Here we see stars ranging from tiny red dwarfs at the bottom to exceedingly massive ones, 50 times as massive as our sun, at the top. The large stars near the top burn

On close examination, this photo of the Scutum starcloud — constituting one tiny corner of our galaxy — records about 100,000 stars! Yet it would take 10 *million* photographs like this one to show *all* the stars present in just our own galaxy! The vast majority are obscured by clouds of gas and dust, some of which darken parts of this view. Most of the other stars in the galaxy can never be seen from our solar system. How few of these stars are parents to life bearing planets? We don't know for sure; we can only speculate, but the odds seem to be getting smaller. In this view, the circle at upper right shows the apparent size of the moon (1/2 degree), and north is at the top. Photograph by Ronald E. Royer.



The above schematic diagrams show the formation of a solar system according to current astronomical theory. (A) An interstellar cloud of gas and dust begins to collapse under the force of mutual gravitational attraction. (B) Because of irregularities in the original motions of the components of the cloud, it assumes an overall rotation as it contracts, with individual particles spiraling into the center of gravity. (C) The cloud rotates faster as it contracts more and more, and the density begins to rise greatly at its center. Meanwhile, other areas of greater density within the cloud begin to collapse independently as they spiral toward the center. (D) Finally the cloud reaches a stable size and ceases contraction as the central temperature and density rises high enough to ignite thermonuclear reactions. A star has been born. (E) A blast of stellar wind from the newly ignited star begins to sweep the system clear of the thin gas and dust. Smaller bodies have formed within the cloud, however, each repeating the larger process, with even smaller bodies forming around them. (F) At last the process is complete, and a stable planetary system has been formed around the central star, each with its own satellites. If any of the secondary bodies had been massive enough to ignite thermonuclear reactions, a double or multiple star would have formed. Otherwise, they slowly cool and become planets.

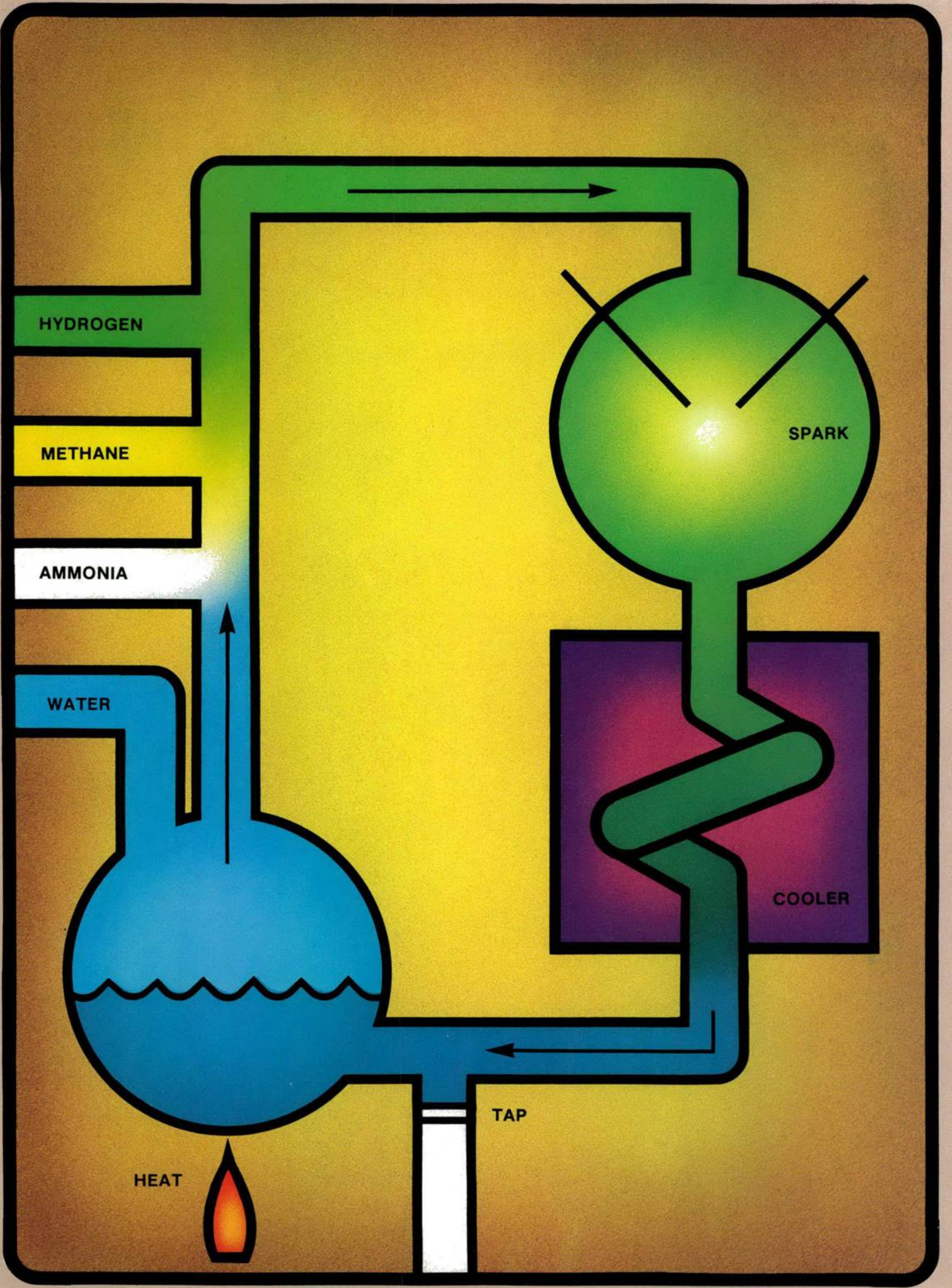
their fuel rapidly and therefore stay on the main sequence for only a few million years. This, of course, isn't long enough for life to develop, so we must eliminate them from consideration.

Now, let's look at the dwarfs near the bottom. They stay on the main sequence for many billions of years so there isn't a time problem with them. Nevertheless, there are problems. Their life zone is narrow and close to the star. If a planet were in this life zone it would experience a particularly large gravitational pull over its surface; eventually it would become "tidally locked" to the star and keep the same face to it at all times. If this happens, there is, of course, little chance that life can arise; temperatures will be extreme.

With the upper and lower parts of the main sequence eliminated, we are left with the average run-of-the-mill types like our sun. As you might expect, our sun is indeed one of the best types. But, just as in a political election, problems can arise even for ideal candidates. If it is in a close multiple system (a group of two or more stars), temperature changes as it moves around in its orbit will likely be too great. So we must also eliminate most multiple systems. Finally, we must also eliminate all stars born during the first billion years of our galaxy's life, because these stars are composed entirely (or at least mostly) of hydrogen and helium. Our candidate must have a suitable system of planets around it. And planets are only associated with stars that have heavy elements and metals in them. (Heavy elements are generated in massive stars that explode and distribute them into space. New stars arising from this material may have planetary systems. For further information, see ASTRONOMY, October 1976.) Taking all of this into consideration we are left with about four billion out of the original 100 billion as candidates.

Next, we must consider the fraction of these

New stars may be forming right before our eyes! In this photograph of M-16, a gaseous nebula in Serpens, several small, dark and compact globules of gas can be seen against the bright background of the nebula. Such objects are known as Bok globules, after Bart J. Bok who first discussed their significance. They are believed to be clouds of gas and dust in the process of contraction due to mutual gravitation. When the temperature and density at the center of the cloud rises high enough, provided the mass is sufficiently great, a star is born. At the same time lesser masses may be forming about the central body, to become a planetary system. Photograph by Hale Observatories.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WATER
SPARK
COOLER
TAP
HEAT

that are likely to have planetary systems. The best we can do here is look at the stars close to us. How many of them have planets? Some astronomers believe that up to a quarter of them may. Of course, the evidence is indirect; we cannot see planets. But by carefully plotting the path of each of these stars over many years, we can see whether or not its path is wavy. If it is, the star likely has a dark companion (the two objects will be revolving one around the other; stretch out their motion across the sky and the result is a wavy line). Peter van de Kamp, a leader in this field, now believes he has found dark companions orbiting several nearby stars. His results, however, are controversial. But we'll be conservative and assume about one star in 10 has a planetary system. In addition, we'll assume that each of them has at least one planet in the life zone. This leaves us with 400 million candidates.

So far we've only been getting our feet wet speculatively. But the next few questions will take us into deeper water. First, what fraction of this 400 million is likely to contain life? Since we can really do little more than guess, let's go all the way and assume that most of them do. The topic is still being debated, but many biochemists believe that with the right conditions and enough time, life is inevitable.

And what about intelligent life? Will it also develop once there are lower forms? For now let's assume that it arises once in 10 times. Our final grand total is then 40 million planets with intelligent life.

But wait! There's still a very important contribution we have not yet included. How long does each of these civilizations last? This depends, of course, on whether or not it develops a technology, but for now let's consider only technical civilizations. Depending on how you define it, we have had a technology from 10 to 1,000 years. How much longer do we expect to be around? The only thing we can say for sure is that we won't last forever; in fact, it's quite unlikely we'll even last another million years.

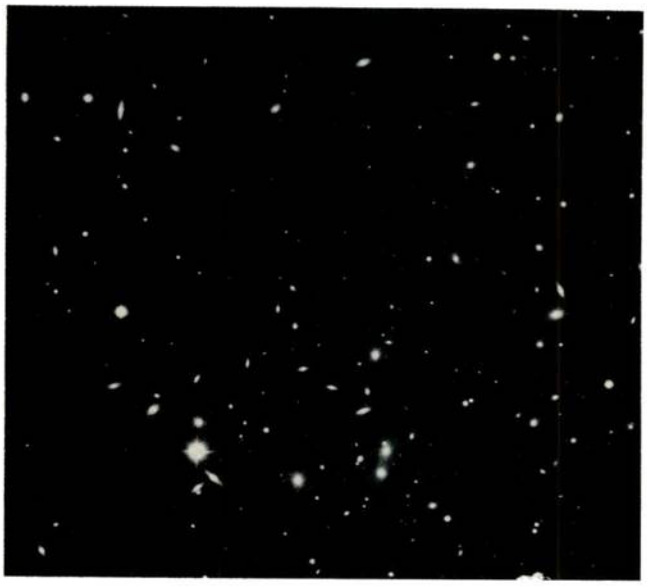
Many scientists believe that once a technical society develops nuclear weapons, its days are numbered. This may be true, but even if a civilization somehow manages to pass through this stage, there will be energy and natural resource problems to consider. Earth's population is increasing at an alarming rate, and a planet cannot continue to support a rapidly increasing population for millions of years.

The step from complex organic molecules to even the simplest, one celled organisms such as the paramecia shown above is a giant one. Scientists are still uncertain of the process by which the necessary constituents of life, whose formation by the reactions shown on the opposite page is well understood, manage to organize themselves into self-replicating, living matter. Without this knowledge, the exact probabilities of life evolving cannot be known. If the probability is very low, as some scientists believe, this would greatly reduce the chances of life appearing on even the most favorable planets. Photograph courtesy of Science News.

The environment of primitive Earth is recreated in this classic experiment on the origin of life. A mixture of vaporized water, ammonia, methane and hydrogen gas is subjected repeatedly to an electrical discharge in the upper right chamber, and then condensed in a cooler back to liquid form. The tap at bottom allows extraction of the liquid for analysis, which proves to be an "organic soup" containing the components of basic life molecules. But it is a big step from the components of life to life itself. Even though scientists theorize that our planet was once covered by an "organic soup ocean", the most recent calculations imply that the probabilities of life spontaneously arising from such a soup are extremely low. It could be that Earth is the only planet in the galaxy which got beyond the organic soup stage! Diagram by Thomas Schroeder.

If we take 100 years as the lower limit of longevity for a technical society and a million as the upper, according to our calculations, we currently have anywhere from 40 to 40,000 advanced civilizations in our galaxy. And any of them should be capable of communicating with us. But how does our estimate compare with those of others? Stephen Dole of the Rand Corporation has used a much more elaborate method for calculating the number of planets in our galaxy suitable for life. This is, of course, less restrictive than our case, as it does not assume the development of life. He showed that there may be 600 million planets that are satisfactory. This could be compared to our 40 million — so at least we're in the right ballpark.

But are we being too optimistic? Let's go back and look at our estimates a little closer. First of all, nowhere have we mentioned the spin of the planet and the angle of tilt of the spinning axis. Both of these are important because they determine our day and give us our seasons. It's not difficult to show that the values they now have are ideal for us. Change the length of the day — either lengthen or shorten it — and you bring disastrous weather changes. Change the angle of tilt and you also bring trouble. Of course, it could be argued that we evolved with our present day and seasons and are therefore



This photograph of a small region in Corona Borealis shows part of the cluster of galaxies known as Abell 2065. Over 40 individual galaxies can be counted in this small area. A test count performed by astronomers in Poland revealed *10,000* galaxies in an area of sky only six degrees square, implying a total of over *11 million* galaxies brighter than magnitude 20.5 (the limit for the Polish study). It has been estimated that over *one billion* galaxies are within the grasp of the largest Earthbound telescopes, and even this figure is only a fraction of the number of galaxies in the universe — which may, indeed, be infinite! Even if it turns out to be true that we are the only intelligent life in our galaxy, there may still be billions of intelligent life forms in the universe — provided there is one in each galaxy. Photograph by Hale Observatories.

adapted to them. Our values might not be critical for another world. But if life is based on the same molecules as it is here on Earth, there would likely be some effect if they were significantly different.

Then there's our atmosphere. Perhaps we should say our "evolving" atmosphere, since that's what we really mean (see ASTRONOMY, August 1978). When life developed we had an atmosphere consisting of methane, ammonia and water vapor (the primitive atmosphere); later it changed to the one we presently have. But there are two planets similar to Earth in our solar system and neither has followed this route. They have atmospheres made up mostly of carbon dioxide; life could not develop or be sustained (actually it is possible that *some* lower forms of life could be sustained) in such an atmosphere. Is it likely that other planets would follow the course of Earth — or would they follow Venus and Mars? Perhaps we need another factor in our calculations to account for this.

These problems are serious enough, but when we start talking about the origin of life we encounter even more serious ones. We know that life first appeared on Earth about 1 to 1.5 billion years after its formation. Intelligent life no doubt took much longer, and technology took about 4.5 billion years. Is this typical? If intelligent life and technology had taken twice as long to develop, Earth would already be on its way to the "bone yard", and the sun would be a bloated giant. Again, how do we even know that higher forms of life would necessarily develop even if the conditions are right? Most biochemists believe that it would, given enough time. But without a doubt, there are problems.

Prof. W. H. McCrea of Royal Holloway College, London, has pointed out one of them. It's generally accepted, for example, that life began in the oceans. How did it get from the oceans to dry land? Tides were likely responsible for sweeping ocean life up onto land, and of course tides on Earth are caused primarily by our moon (some are also caused by the sun). McCrea believes that a planet may need a moon — in fact, one comparable in size to ours — to get life onto the land.

James Christian of Santa Ana (Calif.) College has raised another interesting problem. He has pointed out that there are an extremely large number of different living species on Earth — over a half million plant species, and perhaps as many as one million animal species. Of course, these are only the ones that are around now. If we include all that have existed at one time or another since Earth began, the number staggers the imagination — it may be as high as 10 billion! And of this 10 billion, only one — homo sapiens — has reached higher intelligence. Is this typical of all planets? If it is, we may have to lower our number considerably. Regardless of how optimistic we are with the other factors in our estimate, division by 10 billion leaves a pretty small number!

Let's look at this problem a little further. Most of the numerous species that have arisen on Earth are, of course, lower forms of life. Considerably more evolution is needed to evolve the complex brain and nervous system of man. Certainly we don't know the details, but many billions of accidents of nature (beneficial mutations) must have occurred to give us our highly developed brains. Would exactly these same accidents of nature happen on another planet? Most scientists agree they would not. Indeed, would enough lucky events occur to even give a higher intelligence? We just don't know!

Enough pessimism for now; let's be optimistic for a while and see what happens. Suppose there are a large number of technical civilizations out there somewhere. If this is the case, what can we say about them? About the only thing we can say for sure is that most, if not all, will be more advanced technically than we are. After all, we've only had a technology for maybe 100 years, and astronomically speaking that's an incredibly short time. We might also ask how far away they would likely be. This depends, of course, on how many there are. If there are only about 40, their average separation would be about 10,000 light-years. On the other hand, if there are one million their average separation would be less than 100 light-years.

Ronald N. Bracewell of Stanford University discussed three cases in his book, **The Galactic Club**. He referred to them as abundant life, sparse

OTHER VIEWS...

PRO—

Many scientists still feel strongly that the likelihood of life evolving on other planets is very high. For example, here is the opinion of a physicist:

"What is the evidence for life's existence beyond the threshold of planet Earth? First, there are at least 100 trillion billion ($1x10^{23}$ or *100 sextillion*) identifiable stars within range of our Earthbound telescopes, with each possessing the potential to give vitalization to its own planetary family; this number merely represents what is observable to us within a relatively minor sector of the cosmos. Considering the universe's infinite capaciousness, the potential number of existing planets is virtually limitless!

"However, confined to the clutch of galaxies actually pinpointed by astronomers, a possible one trillion trillion ($1x10^{24}$ or *one septillion*) planets can be presumed to exist, granted an average of 10 planets orbiting each and every star. If but a scant 1/1,000 of one percent harbor the prerequisites for life as we know it, still one million trillion ($1x10^{19}$, or *10 quintillion*) possibilities remain!

"And what of the possibilities for life *not* as we know it? On our own planet, contradictions abound in sufficient quantity to cause us to ponder what diverse life forms may have evolved elsewhere in the universe in supposedly hostile environments. If anaerobic bacteria can survive in airless vacuums, then why not on oxygen-free asteroids? If mites are able to subsist in methane filled vessels in terrestrial laboratories, then why not in the Neptunian welkin?

"But even if a broad spectrum of life forms has developed throughout the cosmic expanse, is there any reason to believe that beings technologically superior to us indeed exist? Statistically, it would be most surprising if there were none! The conclusion is inescapable: A myriad of planets are presently serving as the habitats of societies far in advance of Earth's (a disquieting notion, to say the least).

"Moreover, once a civilization enters the Atomic Age, its progress increases exponentially, so that a difference of 100 years can mean a tenfold increase in technological superiority. As an illustration, a 12th century Florentine would not have been taken aback by the progress his 13th century counterpart had made, but an 1879 Philadelphian suddenly teleported to 1979 would definitely suffer from severe future shock!

"Imagine, then, what a difference of 100, 1,000 or even 1,000,000 years would mean in terms of the potential for interstellar space travel. It is merely a matter of time (albeit perhaps as long as 1,000 years) before we ourselves encounter alien civilizations in the vast recesses of this universe and learn how unique we are *not*!"

—Franklin R. Ruehl

AND CON—

But a growing number of scientists are not so sure. Dr. Iosif Shklovskii, the eminent Russian radio astronomer who co-authored the classic work **Intelligent Life in the Universe** with Carl Sagan, now believes that more recent astrophysical discoveries have significantly reduced the probabilities of the occurrence of intelligent life. He is joined by the authors of two recent books.

Sir Bernard Lovell, a famed British astronomer, believes that our presence on Earth is the result of a train of events so unlikely as to reduce to zero the chances of intelligent life evolving elsewhere in the galaxy. He argues that the gaps in our knowledge of the processes involved in the evolution of life in the universe make it impossible to calculate firm probabilities. Combined with what knowledge we do possess of the nature of stars and galaxies, and the explosive events to which they are subject, he concludes that while we can't be certain of the exact figures, the odds do seem to be very high that life, and especially intelligent life, is an *extremely* rare phenomenon in the universe.

And Nigel Calder, England's foremost science writer, agrees. In his new book **Spaceships of the Mind**, he states his belief that we are indeed the only intelligent life to be found in our galaxy. He admits that this is a minority view at present, but asserts that his negative evaluation is gaining credence among scientists as more and more is learned about the nature of our universe and the processes taking place in it.

Noted physicist and cosmologist John Wheeler goes even further. In his view, the chances are overwhelming that we ourselves are the only life in the entire universe! Wheeler may represent the most extreme, though least widespread, evaluation of the chances, but it cannot be denied that more and more scientists are becoming increasingly skeptical about the possibilities of extraterrestrial intelligent life. Perhaps we *are* alone, at least in our own galaxy, they are saying. Faced with the same thought, the French philosopher Blaise Pascal wrote long ago, "The eternal silence of these infinite spaces frightens me."

life and rare life. These classifications depend primarily on the average longevity of advanced civilizations. According to his calculations, if there is abundant life in the universe, the average separation will be only about 30 light-years; if there is sparse life it will be 30 to 300 light-years, and if it is rare it will be greater than 300.

How could we contact one of these civilizations? Certainly we couldn't jump into a spaceship, fly off and visit them on Sunday afternoon. But there is hope with radio waves which travel at the speed of light and, relatively speaking, are not extremely expensive. If there was a technical civilization 30 light-years from us, we could get a message back in 60 years. If they were 1,000 light-years away we would, of course, have to wait much longer — 2,000 years.

Two way communication is obviously not going to be fruitful. Perhaps all we can really hope to do is just detect them. Maybe one of them is beaming a message our way; after all, we have recently beamed a message toward the Hercules cluster. But even if this isn't the case, we may be able to detect stray radiation that has leaked off into space from their planet. As we will see later, there is considerable leakage of this type from Earth.

If there actually are advanced technical civilizations, how likely is it that we could detect them? Let's begin by considering what we might call "supercivilizations". Suppose a certain small fraction, say one percent, of all civilizations are extremely long-lived and develop a highly sophisticated technology. Eventually they would be able to travel to nearby stars. (We may have the technology to do this within a few hundred years.) And, of course, soon after they traveled to the nearest star they would be off to others. (We might call this "star hopping".)

It is interesting to ask how long it would take to travel long distances in space this way. Let's assume, on the average, that they travel through our galaxy at about the speed Earth orbits the sun (18 miles per second); this is 1/10,000 the speed of light. In a million years they would have moved out 100 light-years from their star. And they would likely have colonized many of the stars they visited along the way. In 100 million years they would be 10,000 light-years from home base. And again, they would likely have continued colonizing as they went (note that this is 1/10 the distance across our galaxy). One hundred million years may seem like a long time, but it is less than 1/1,000 the lifetime of our galaxy. And it is possible that a civilization (assuming it developed) has been around that long.

Freeman Dyson, of the Institute for Advanced Study, has devised a scheme for classifying civilizations. He refers to them as type I, II and III. We are a typical type I civilization. Type IIs use most (or all) of the energy output of their star, and type IIIs have migrated out and now control a large fraction of their galaxy.

Could we detect type III civilizations? Easily, even if they were not beaming a message our way. Here on Earth we are advertising our presence with a considerable leakage of radiation into space. High powered UHF-TV stations are mainly responsible for this stray radiation. It began about 20 light-years ago and is still moving outward from us at the speed of light. Earth is, in fact, surrounded by an expanding envelope of radiation, 20 light-years in radius. Other civilizations would likely betray their presence in the same way. And even if they eventually developed techniques to stop this loss, we would still likely be able to detect them. They also give off a considerable amount of infrared radiation.

Have we detected any signs of such radiations? So far we have detected nothing. Many astronomers will argue, however, that our search has just begun. And this is, to some degree, true. But as Dyson points out, a type III civilization would be "glaringly obvious".

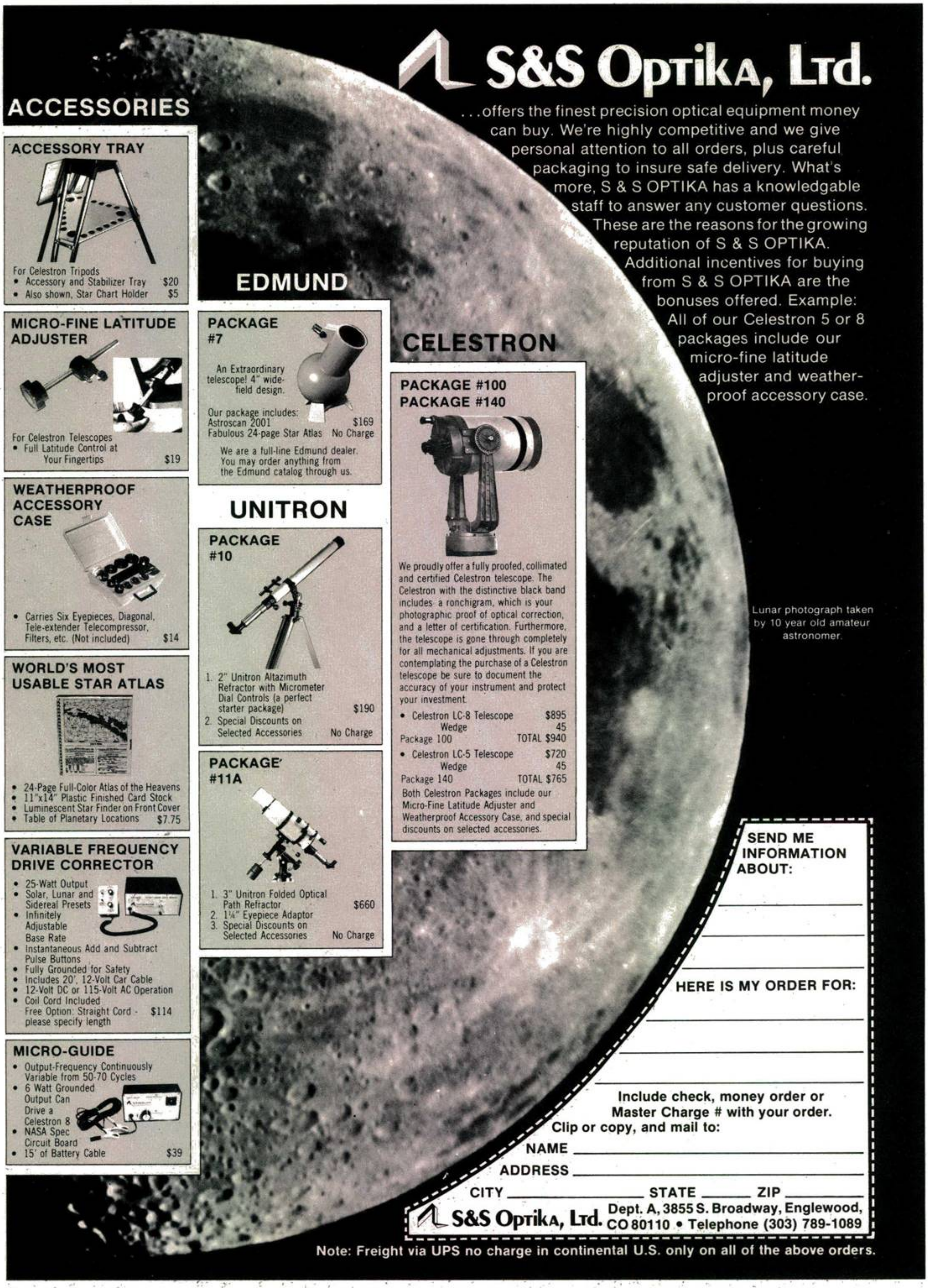
Dyson said, "I have the feeling if an expanding technology ever got loose in our galaxy, the results would be glaringly obvious.... Nothing like a complete technological takeover ever occurred in our galaxy. And yet the logic of my argument convinces me that if there were a large number of technical societies in existence, one would probably have carried out such a takeover. So in the end I am skeptical about the existence of any extraterrestrial life. Maybe the evolution of life is a much less probable event than molecular biologists would have us believe. Or maybe intelligence doesn't always develop a technology...."

Who knows! Perhaps we could argue that the chances of a large scale takeover of our galaxy are quite small. And besides, there are almost as many galaxies in the sky as there are stars in our galaxy. What about one of them? With this in mind, Sagan and Drake have recently been looking at entire galaxies. So we can still keep our fingers crossed (but imagine the difficulty of trying to communicate with them).

As we look at the situation for our galaxy we see problems at both ends. The odds seem to be strongly against an intelligent civilization, and even if we argue that things are really not that bad we wonder: If there are numerous advanced civilizations, wouldn't one of them have taken over part of our galaxy? And if so, why haven't we detected it?

The difficulties are hard to fathom, but the rewards are well worth the search. Think of it — the discovery of an intelligent race of beings on a planet out there; it would certainly be the most exciting discovery we could ever make! ◆

Barry Parker is an associate professor of physics and astronomy at Idaho State University, where he has taught courses in descriptive astronomy, astrophysics and cosmology. His main interests are black holes and cosmology, and he is currently writing a popular level book on the latter.



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IS THERE A "NEW" LUNAR CRATER?

by

Joel Davis

translations from Latin by Richmond Hathorn, SUNY Stony Brook

"This year, on the evening of June 18, when the moon, a slim crescent, first became visible, a marvelous phenomenon was seen by several men who were watching it. Suddenly the upper horn of the crescent was split in two. From the midpoint of the division a flaming torch sprang up, spewing out over a considerable distance fire, hot coals and sparks. The body of the moon which was below writhed like a wounded snake. This happened a dozen times or more, and when the moon returned to normal, the whole crescent took on a blackish appearance."

A fanciful story? Illusion? *Delusion*? Maybe a bit of all three, but planetary scientists are now considering that it may be an eyewitness account of a lunar crater being formed! The year was 1178, and the description comes from the chronicles of Gervase of Canterbury. In his account for that year he noted the event had been seen by several monks who were "prepared to stake their honor on an oath that they have made no addition or falsification in the above narrative."

Assuming they weren't suffering delusions, what did they see? Is it possible these monks actually witnessed a meteor impact on the moon? It's not likely we'll ever know for sure, but evidence points strongly to this conclusion!

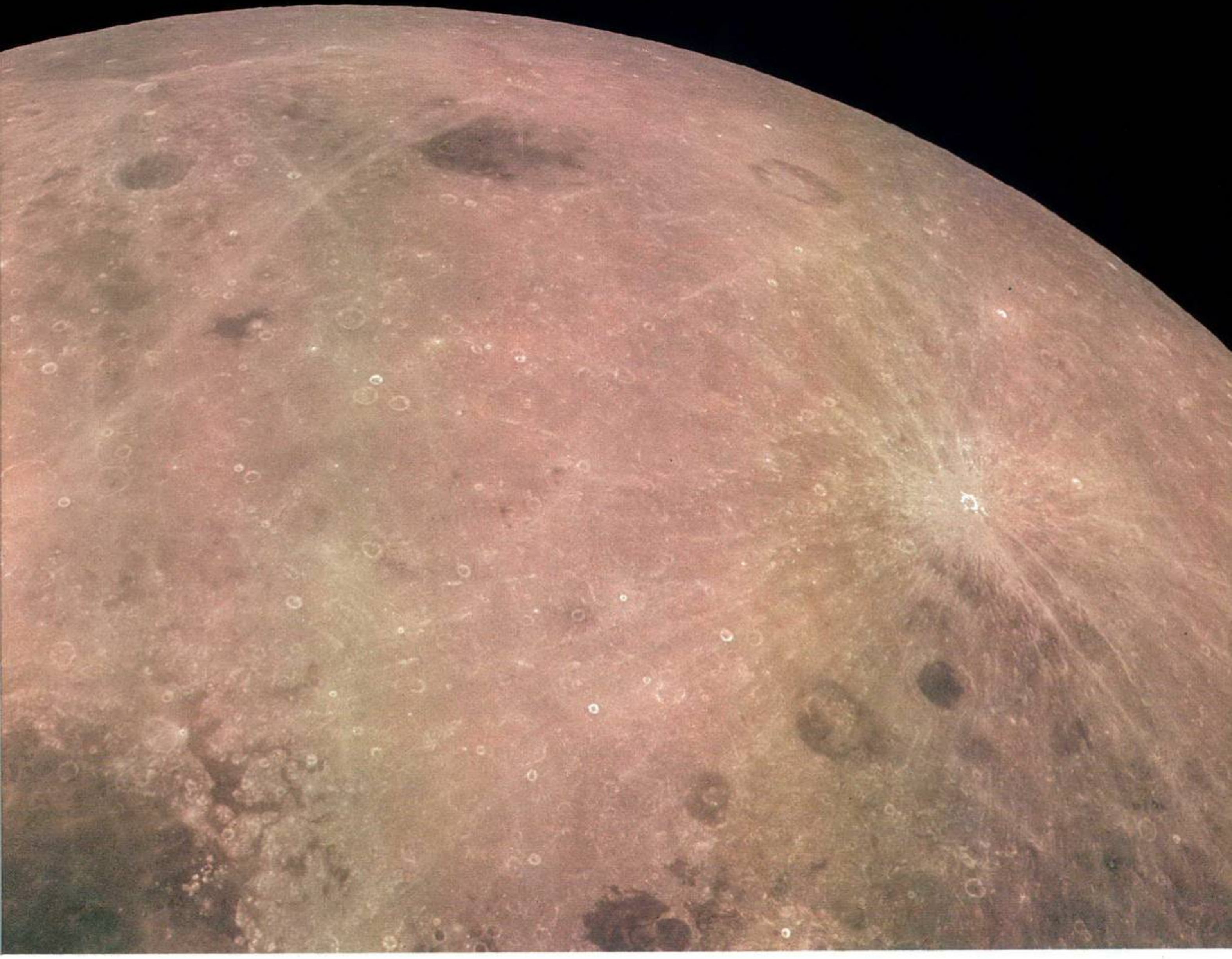
Apollo samples have shown that the period of heavy cratering on the moon (and also Earth) ended a long, long time ago. It isn't very likely that any sizable lunar craters have been formed in historical times, apart from microscopic and occasional small rock impacts. But on the other hand, there isn't any reason why a meteor *couldn't* have hit the moon 800 years ago. It could happen again tonight, though the odds are heavily against it.

Dr. Jack Hartung, of the State University of New York at Stony Brook, looked into the matter when his attention was drawn to the report in the old chronicle. Assuming it was a meteor impact, Hartung compared the account with lunar photos and established some rough limits on where it could have happened. The most likely candidate turned out to be the crater Giordano Bruno, a pit 20km (about 12 miles) in diameter located at longitude 103 degrees east and latitude 36 degrees north, past the eastern limb of the moon,on the farside.

Bruno's an interesting crater. The rim is very sharp edged, giving it an overall fresh and "unweathered" look. Bruno also has an extensive ray system, with the longest rays for its size of any crater on the moon. Rays in general appear to be formed from material splashed up and out of the impact zone. The longer a crater has existed, the more subsequent impacts cover or destroy its rays. The continuous rain of micrometeors and solar wind eat away slowly at the surface, softening contours and obliterating details. With such an extensive and well delineated ray system, Bruno must be a young crater indeed.

If Bruno, then, is the prime candidate for the site, some questions arise: First, would the impact have been visible from Earth, and second, would it have left any effects we can see, apart from the fresh appearance of Bruno? The answer to the first question is a resounding yes, and the second only slightly less so!

Two scientists at France's Center for Geodynamic and Astronomical Study and Research, Odile Calame and J. Derral Mulholland, analyzed the possibilities. They sought to determine

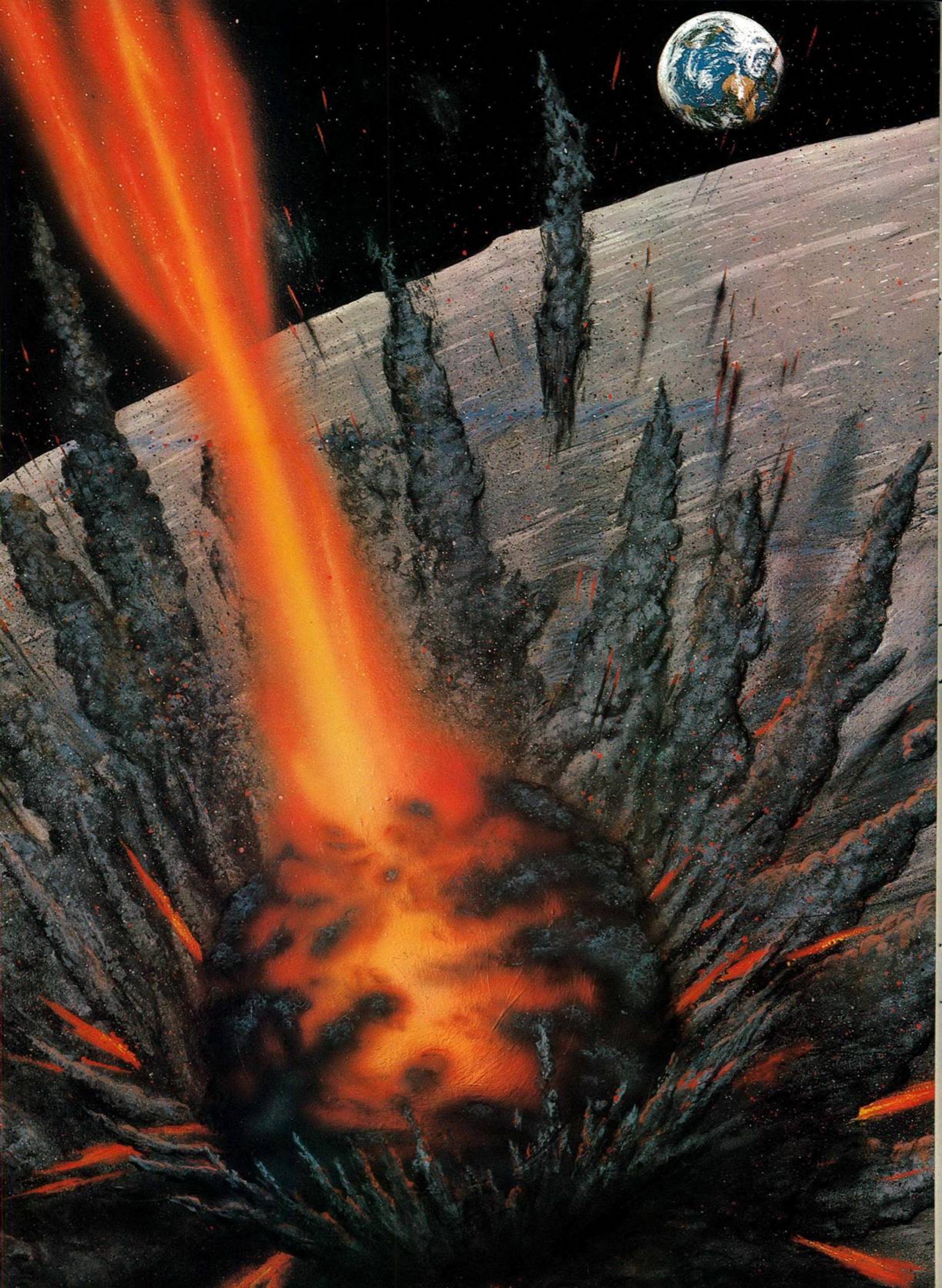


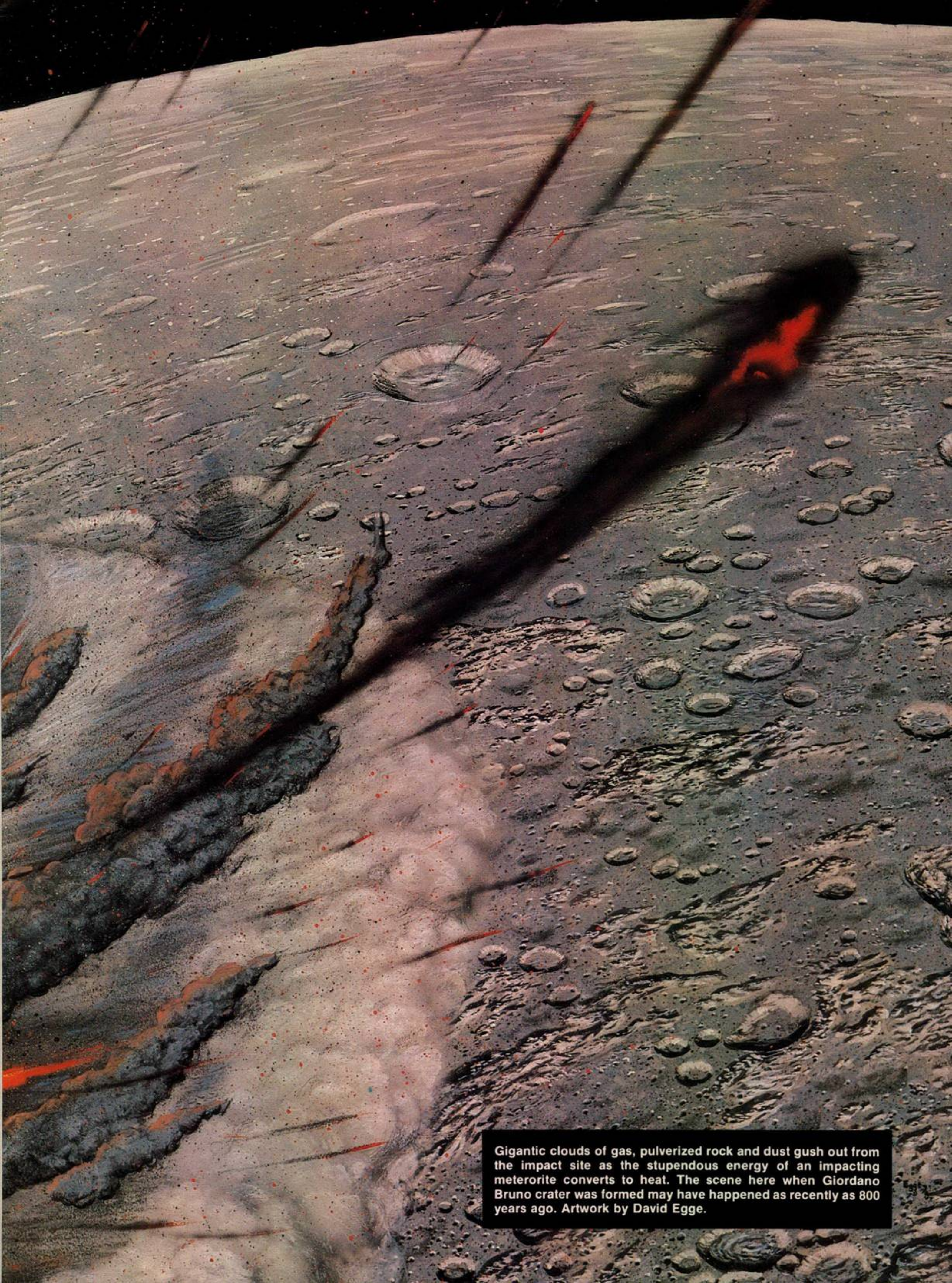
if the supposed impact would have been visible from Earth, and if there were any present irregularities in the moon's motion that could have come from such an impact.

Bruno lies on the lunar farside, about 370km (230 miles) beyond the moon's right hand edge (see the diagram on page 23). On June 18 (or June 25 in the currently used Gregorian calendar) in 1178, the moon was 1-1/2 days past new. The terminator that evening was some 840km (about 520 miles) to the west of the crater. For the impact to have been noticed from Earth, the tower of ejected material would have to have been about as high as the visible width of the crescent, or about 400km (250 miles). Moreover, a significant flood of ejecta would have to have been blasted over the limb and across the terminator for the two horns of the crescent moon to have looked separated, as Gervase of Canterbury claimed they were.

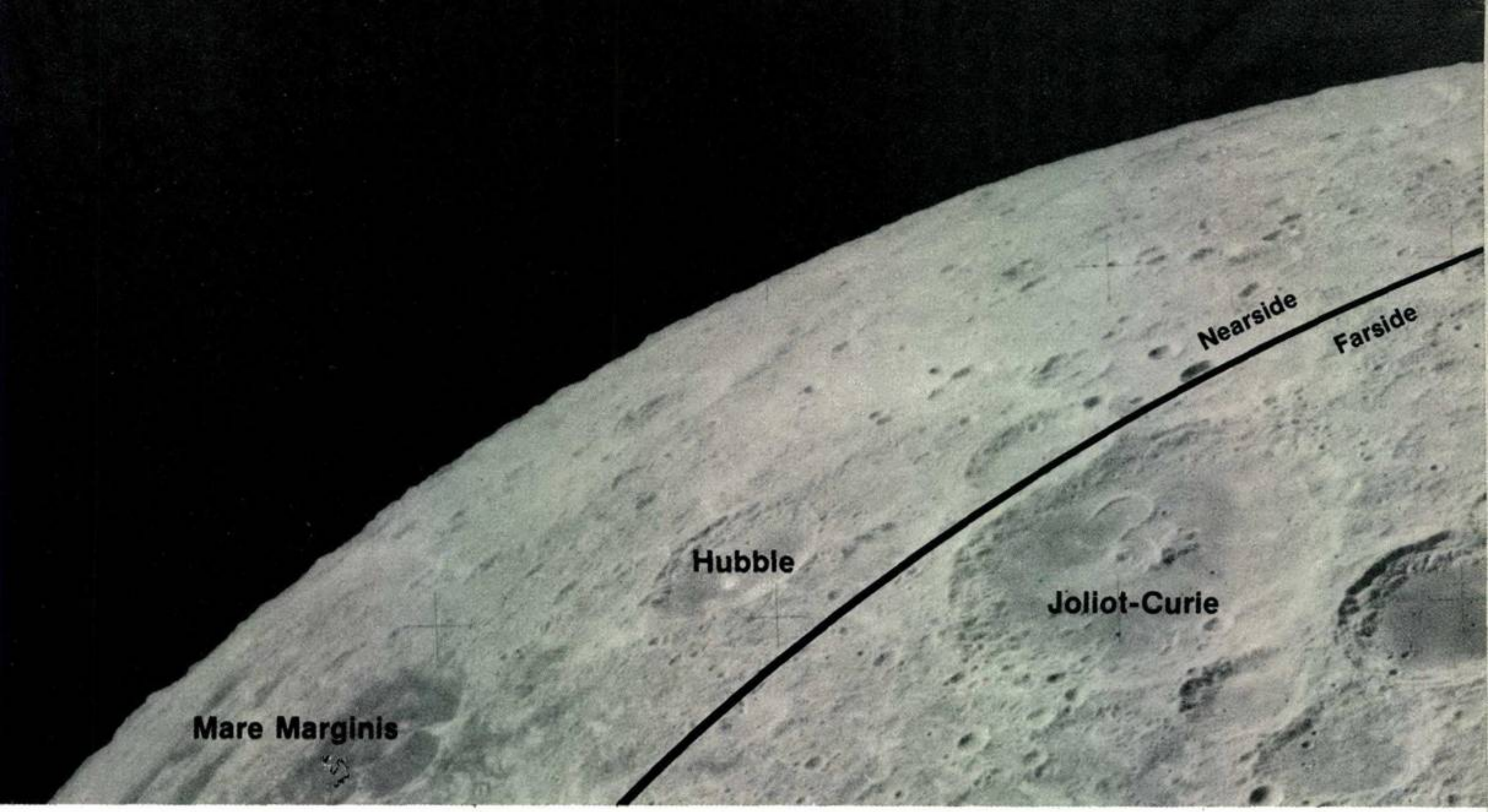
The bright splatter of rays from the object at right center spreads out from Giordano Bruno, a fresh crater on the lunar farside. At the lower left is the northeast corner of Mare Crisium, a familiar nearside feature. Bruno's formation may have been witnessed in the year 1178 A.D.! NASA photograph.

To start on the problem, Calame and Mulholland had to make some assumptions. They assumed that about one percent of the ejecta would have been completely blown off, accelerated past





Gigantic clouds of gas, pulverized rock and dust gush out from the impact site as the stupendous energy of an impacting meterorite converts to heat. The scene here when Giordano Bruno crater was formed may have happened as recently as 800 years ago. Artwork by David Egge.



lunar escape velocity. Second, they assumed that a sizable remainder would have fallen between 500 and 1,200km (300 and 750 miles) out from the impact point. Lastly, they assumed (for dynamical reasons) that the angle the ejecta was thrown out at was between 45 and 85 degrees from the vertical. They had to choose surface limit distances because orbital photography shows Bruno's rays extending at least 500km, and because the Russian lunar probe, Luna 24, seems to have landed on a Bruno ray 1,200km from the crater. Raylike material was returned in its sample.

When they performed the calculations, they were impressed! Not only could the ejecta have traveled the width of the lunar crescent, but it also could have *easily* traveled the 1,200km corresponding to the outer limit! The event was violent and would have looked apocalyptic enough to justify the description in the chronicle. Had the impacting object been a cluster of bodies, then several fiery torches might have resulted — just as the chronicle recorded.

This settled the visibility test. The other test, that of irregularities in the moon's motion, is less precisely answered.

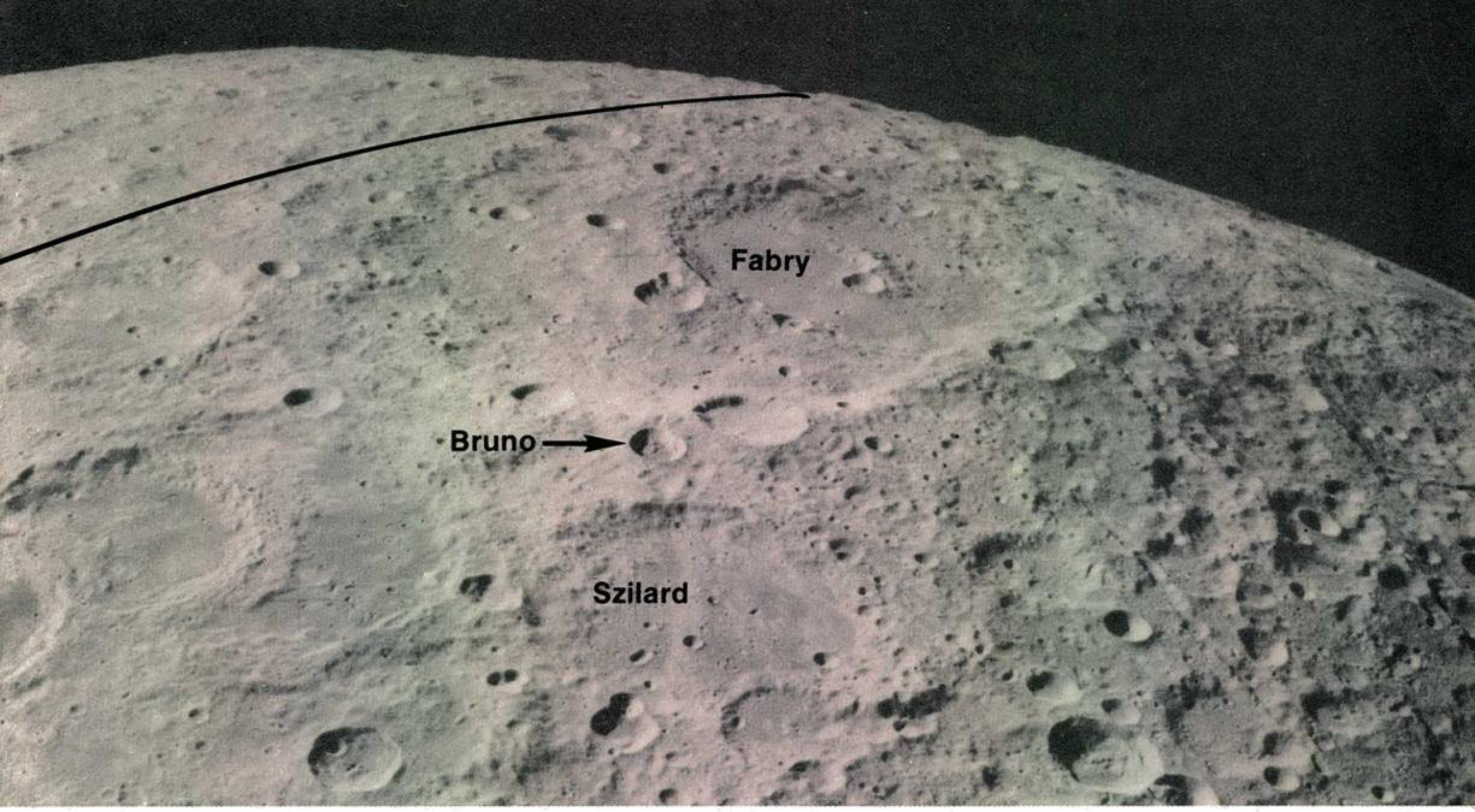
The moon moves in a variety of ways stemming from various causes. One of these is a slow wobbling from side to side, allowing us to peek at times a bit past the east or west limb. This wobble, called *libration*, is well-understood. Impacts on the moon cause another form of libration, called a *free* libration. When a meteor slams into the moon, the moon reacts, showing an effect in its motion: the larger the slam, the greater the effect. After a while, motions caused by the impact would subside to nothing, though the timescale might be long in human terms. If there was an impact back in 1178, and if it was hefty enough, the effect might still be detectable.

But you wouldn't detect it by visual inspection! The crater of Bruno is only 20km across, so the meteor couldn't have been very large. The wobbles imparted to the moon by its impact would be far too small to detect by the eye, even right after the event. A far more sensitive test is needed, but only since 1969 has such a test been possible.

The Apollo crews visiting the moon left an instrument at each site, the passive retroreflector, whose highly polished, closely aligned mirrors have allowed Earth based lasers to determine very precisely the Earth-moon distance. They're sensitive enough to measure any wobble remaining from the postulated Bruno impact. Calâme and Mulholland examined the data from the retroreflector experiments since 1974 to determine the extent of any free librations in the moon's motions.

In the analysis, not only did they see a librational wobble, but the amount closely matched the proposed value from impact at Bruno! The moon is still staggering from the slam of the object(s) that blasted out the crater — 800 years after the event!

But this doesn't yet amount to proof that Giordano Bruno crater was created June 18, 1178. It simply makes it a very good possibility. Several scientists have suggested that what the monks saw that summer evening was a meteor entering Earth's atmosphere, just across the crescent moon. If positions were right, then the effects might be similar, especially to startled witnesses. But going



against this hypothesis is the great unlikelihood that all the elements were *so* precisely aligned.

Others have objected that a meteor impact simply wouldn't have been visible from Earth. But while no one has yet seen a large impact in recent times, it's clear that a lot of gas and pulverized rock shoots out from the site in the explosion. And if the brightness of the debris were somewhat different from the rest of the moon's surface — a sensible assumption — then it would have stood out in contrast. Boiling with inner turbulence as it obscured the light of the moon, the cloud could have made the crescent "writhe like a snake".

So what did happen on the evening of June 18, 1178? Possibly this:

Five monks standing outside are looking at the thin crescent of the moon, 240,000 miles away. A cluster of objects — possibly the head of a dead comet — traveling more than 20km per second hits the moon beyond the limb. The sight becomes awesome. The unimaginably great kinetic energy of the meteors is released and a gigantic plume of incandescent gases and powdered lunar rock leaps up and out from the moon. The hot gases flame like a torch.

Part of the material, flung out at more than 2-1/2km per second, escapes from the moon altogether. Some of this may eventually enter Earth's atmosphere as meteors; the rest will dissipate into the vastness of the solar system.

Most of the gas and dust is thrown violently out of the impact area in every sort of trajectory, all less than lunar escape velocity. The ejecta may be darker than the surface of the moon, so as the gases, pebbles and rocks fly across the landscape, five monks near Canterbury, England see a thin crescent moon suddenly cut in half.

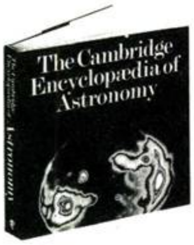
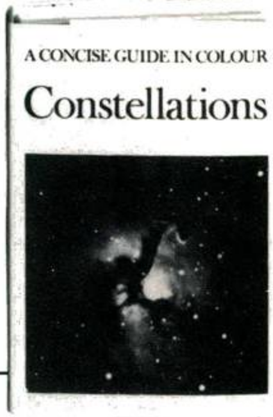
Part of the moon's farside and nearside limb areas is shown in this finely detailed photo from the panoramic camera aboard the Apollo 16 command module. The view is to the northwest, and various features on both lunar hemispheres have been marked. NASA photograph courtesy of the Lunar Science Institute.

(Did anyone else see it? Over England and Europe, darkness was falling. Probably others noticed the strange event, but if they ever wrote an account, we've yet to find it.)

The moon rings like a bell from the impact. Perhaps the blast triggered a volcanic eruption, or maybe the "meteor" was a cluster of objects. But as the monks watch, they see more flaming torches spurt from the moon's side. Eventually the outbursts subside and quiet returns to the moon, under a dim atmosphere of dust.

To observers on Earth, the crescent looks darker. The thin turbulent atmosphere generated by the blast refracts light, making the sliver of moon writhe and twist. Beyond the limb, a new crater glows red hot under the pall of dust. The ejecta begins to settle out in long streamers, brightly reflective, some stretching more than 1,200km from the angry wound in the moon's surface. Soon the atmosphere goes, and the crater cools. At last, all returns to normal with nothing more to show than a sharp edged crater, bright rays and a tiny wobble slowly dwindling over the centuries.

Joel Davis is a science writer living in Spokane, Wash. He is currently working on articles about supernovae and the upcoming total solar eclipse (Feb. 26, 1979) for Spokane area newspapers.

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SKY ALMANAC

Jupiter Comes to Opposition

The big event for these long, cold nights is the opposition of Jupiter, now in the sky throughout the whole night. Jupiter's one of the easiest of the planets to observe, so if you're new to astronomy, give it a good look!

Upcoming Events — February

4	First Quarter Moon
5	Occultation of Aldebaran
9	Mercury at superior conjunction
12	Full Moon
13	Moon 3° south of Saturn
19	Uranus 4° south of the moon
26	Total eclipse in western North America!
27	Conjunction of the moon and Mercury

The occultation of Aldebaran will be a favorable event, occurring as it does on the dark limb of the moon. The northwestern third of the United States and the western half of Canada miss out on the occultation, since they're north of the northern limit for the event.

The following table gives locations and times (in UT) for places in North America:

Texas	22 h 09 m
New Mexico, Arizona	22 h 14 m
Alabama, Georgia	22 h 26 m
California	22 h 27 m
Colorado	22 h 32 m
Illinois	22 h 36 m
Washington, D.C.	22 h 49 m
Toronto	22 h 57 m
Massachusetts	23 h 03 m
Montreal	23 h 09 m
Nova Scotia	23 h 22 m

Be sure to be ready and watching *before* the times given here! The times are for "standard stations" and you will be probably observing from a different locality — which means your occultation time will be different, too.

The total eclipse will be an exciting event; see the November 1978 issue for details!

A day later (the 27th), look for a close approach of Mercury and the moon; observers in the southern parts of the western hemisphere will see an occultation.

Mercury

During the first 7 to 10 days of January, Mercury will be visible over the eastern horizon, but if you're keen about seeing it, don't wait too long! By the 9th, the quickly moving planet will be very low at sunrise. In its orbit, Mercury is heading swiftly for superior conjunction (which comes in early February).

On the 5th, a telescope will show you a gibbous disk 5.5 seconds of arc across. On that date, it'll be 1.2 astronomical units (AU) away from us, or 112 million miles (180 million kilometers). See last month's Gazer's Gazette for a chart of Mercury's position relative to the eastern horizon.

Venus

The cloud veiled second planet from the sun is the unmistakably bright object in the southeastern sky before dawn. Rising about 1 hour 45 minutes before the sun, Venus will cross from Libra into Scorpio on the 8th, putting it some 12 degrees northwest of Antares. If you're lucky, and have a clear view to the east with no clouds or haze, you may be able to glimpse the ruddy eye of the scorpion shining at magnitude +0.9. Try for it!

On the 18th, Venus will be at greatest western elongation, some 47 degrees from the sun. With a telescope, look for a 25 second of arc disk of magnitude -4.1. It'll appear half lit, and will resemble a featureless quarter moon.

Earth

On the Jan. 4, at 22 hours UT, Earth passes through its point of closest approach to the sun (called *perihelion*). The sun will then be 0.9833 AU (91 million miles, or 147 million kilometers) from us.

It's a coincidence, but the very shape of Earth's orbit works fortuitously for us: During our winter, the large land masses of the northern hemisphere could produce very cold winters indeed as the expanses of land rapidly give up their heat to the atmosphere. But when perihelion, with its greater influx of solar radiation, comes shortly after the solstice, the impact is softened and the wintry blasts are slightly abated. In the same way, the largely "wet" southern hemisphere has its winters eased partially by the vast expanses of heat-retaining ocean.

Mars

The red planet is in conjunction with the sun at 12 hours UT on the 20th. You'll have a very hard time looking for it!

Jupiter

The giant of the solar system moves into opposition with the sun on Jan. 24 at 15 hours UT. During the whole month, you'll see the planet blazing at magnitude -2.2, overpowering the dimmer stars of Cancer, its temporary home constellation.

Take your binoculars or a low power telescope and be sure to look at the planet during the first few days of the month, when it'll be passing just to the south of the Beehive cluster (M-44)!

Saturn

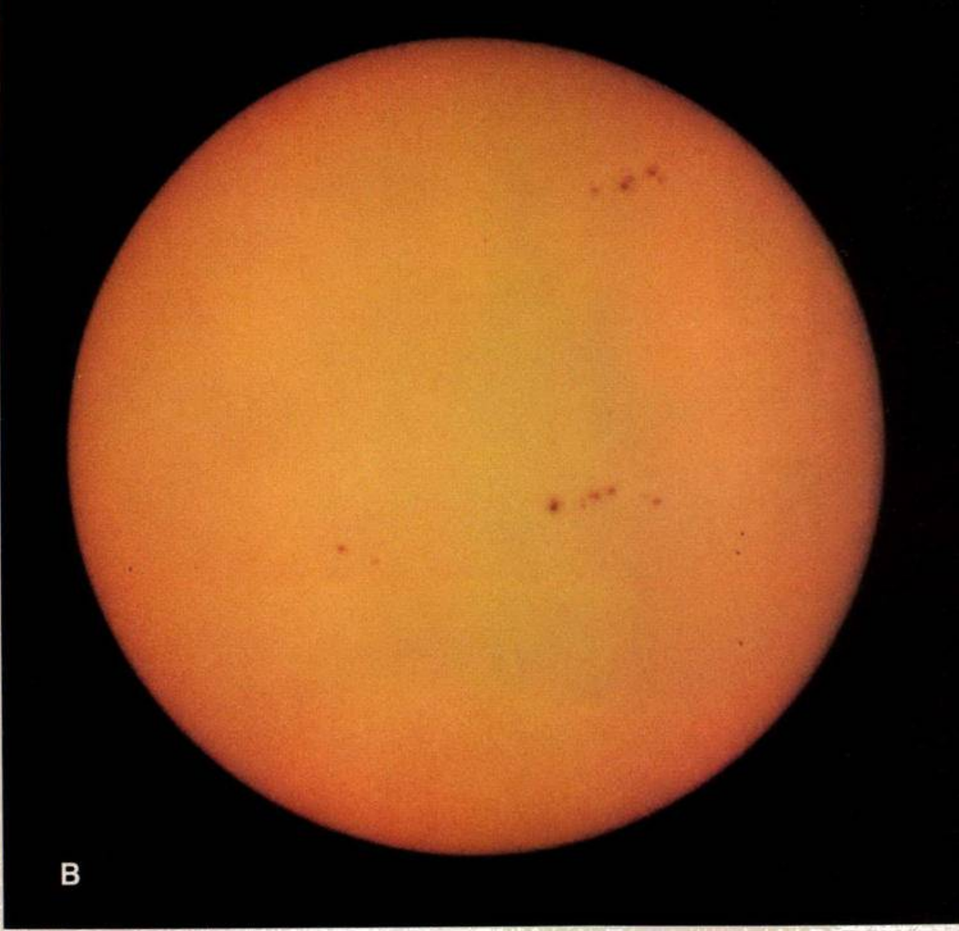
Saturn moves ponderously in a 30 year orbit of the sun. Now retrograding slowly in southern Leo, the ringed planet will spend the whole month close to the double star Chi Leonis. The Chi Leonis system consists of a 4.7 magnitude primary star and an 11th magnitude companion very close by. The primary will be visible to the naked eye, of course, but you'll need a telescope to go after the faint companion, just three to four seconds of arc away.

Uranus

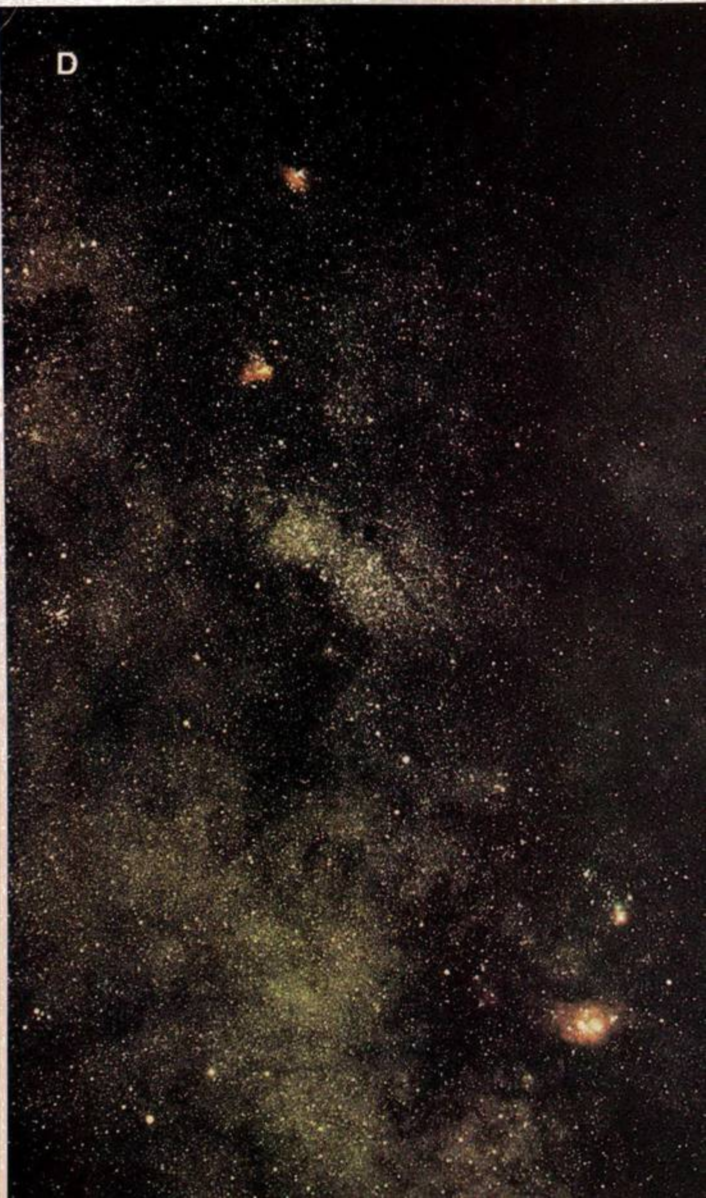
Our second ringed planet is now crawling eastward through south central Libra. On the morning of the 11th, you'll find Uranus some 2-1/4

A: M-15, a bright globular cluster in Pegasus (photograph by Bill Iburg); B: the sun, Aug. 26, 1978, showing many prominent spots (Tom Koed); C: NGC-7293, a planetary nebula in Aquarius (Bill Iburg); D: the southern Milky Way in Sagittarius (Brad Wallis and Robert Provin).

A


B

C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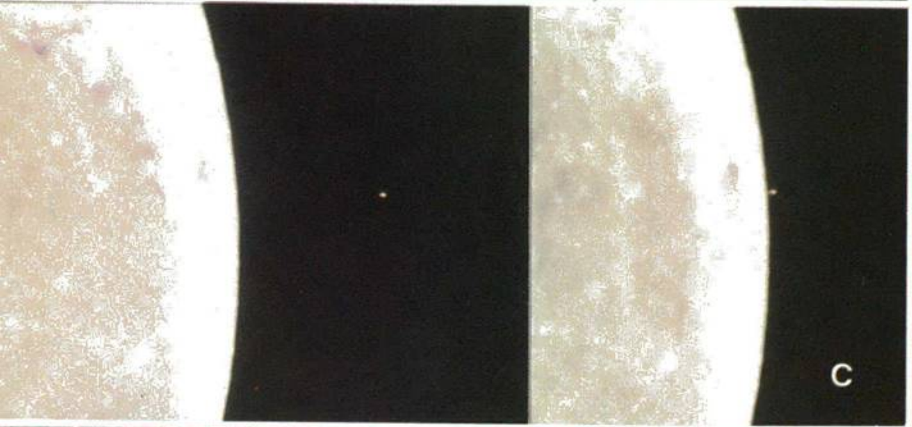
A

B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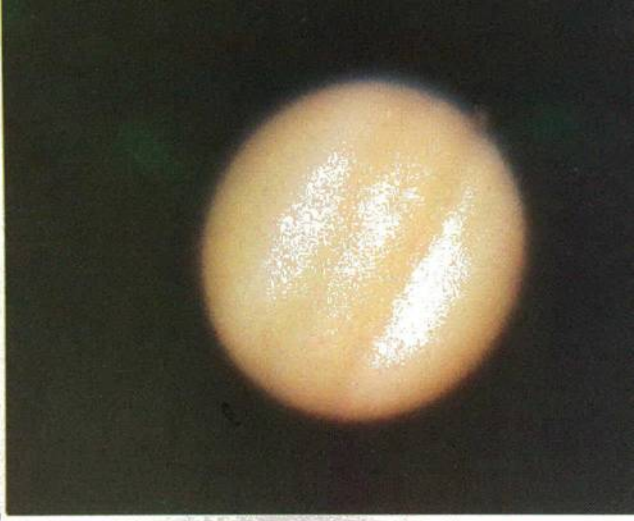
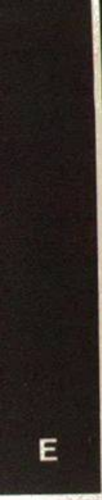
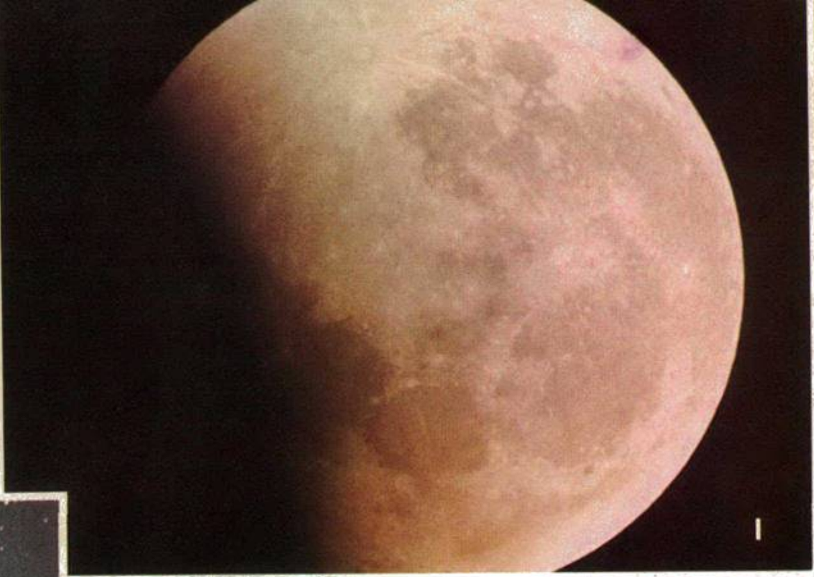
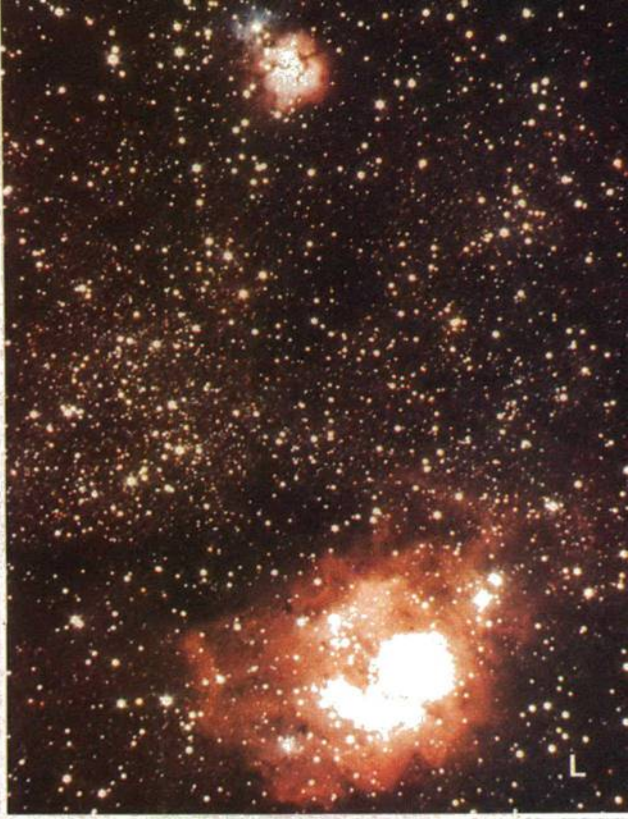
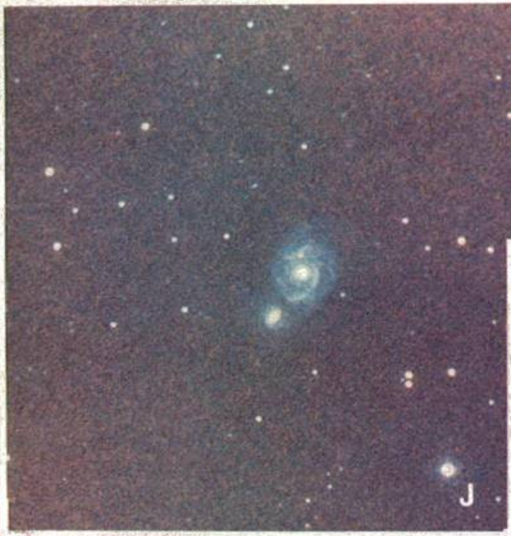
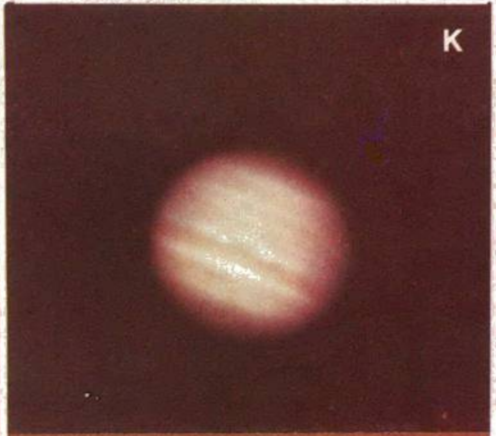


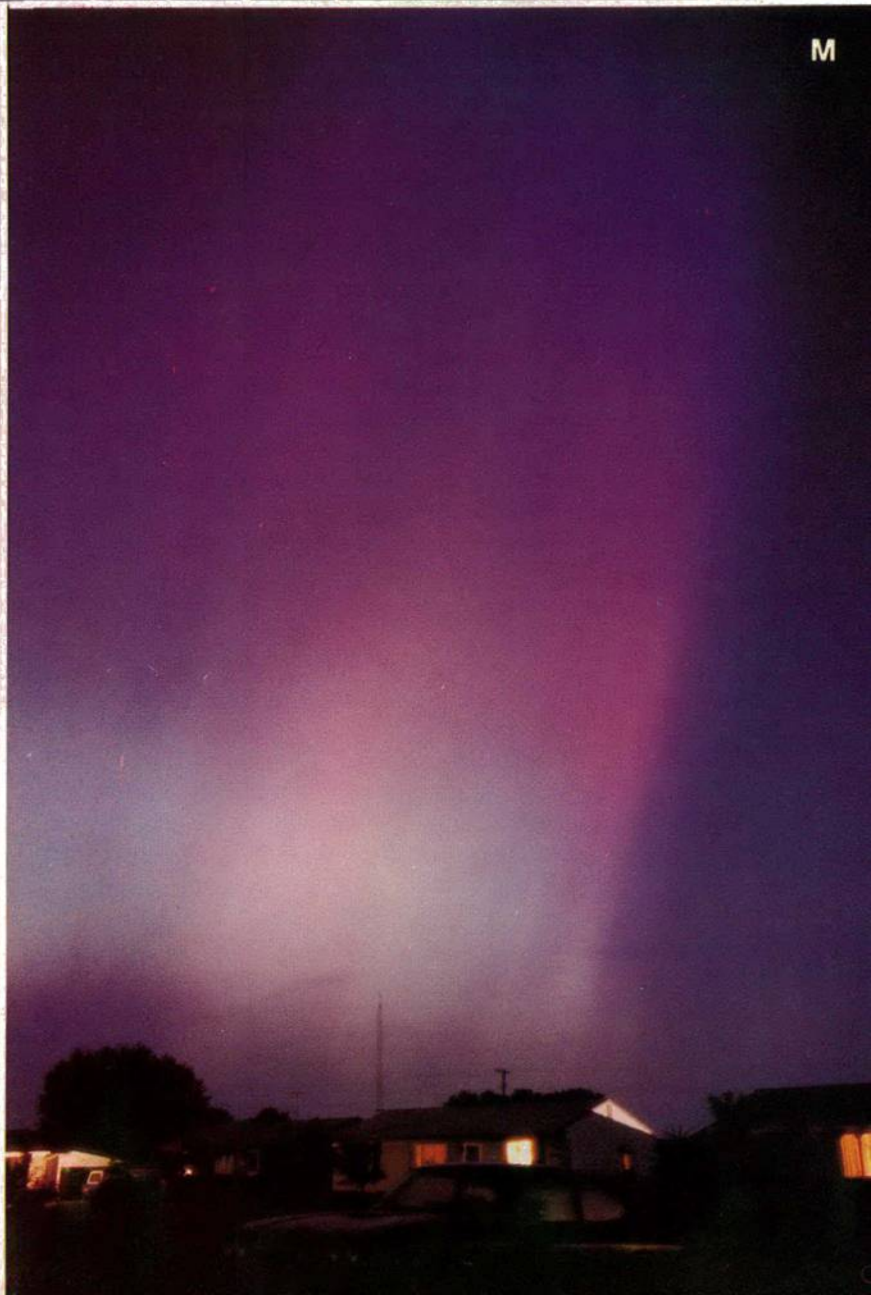






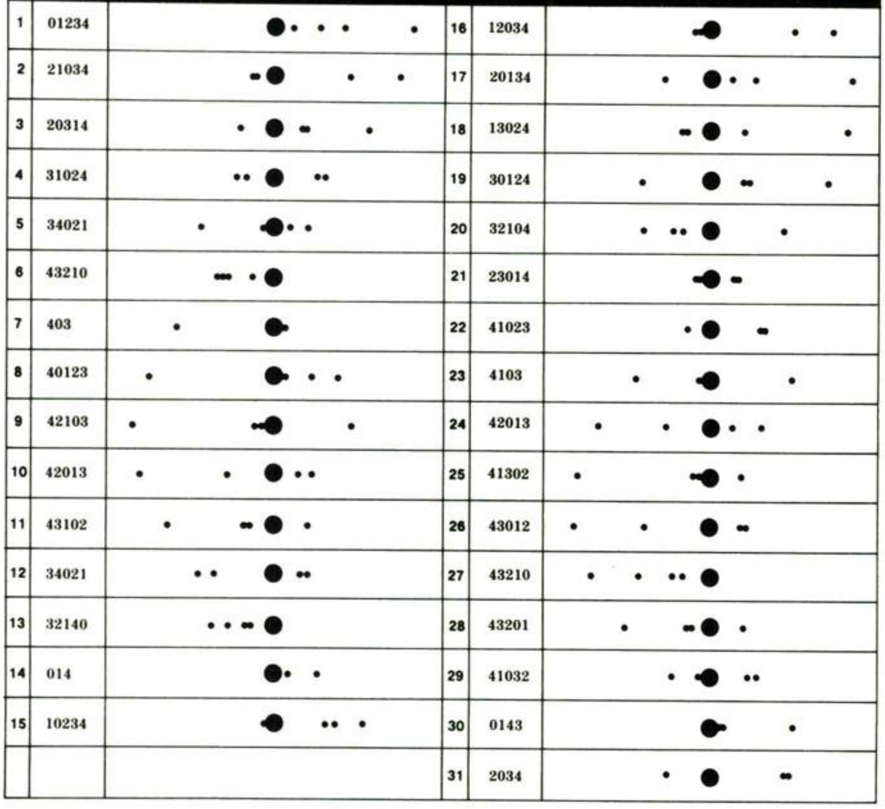






A and *B*: Aurora on Sept. 29, 1978 from Dover, N.H. (photograph by L. H. Price); *C*: occultation of Aldebaran, Sept. 22, 1977 (G. Fanning); *D*: Deneb and the North American nebula (T. S. Ellis); *E*: Io ends its transit of Jupiter's disk, Dec. 27, 1977 (James R. Felbab); *F*: Zeta Orionis and the Horsehead nebula (Mark A. Croom); *G*: M-17, the Omega nebula, in Sagittarius (Robert Provin); *H*: mock suns (Jeff Ehlinger); *I*: lunar eclipse as seen from Czechoslovakia, Sept. 16, 1977 (Jozsef Habina); *J*: M-51, the Whirlpool galaxy, in Canes Venatici (Brad Wallis); *K*: Jupiter (Don Primi); *L*: Trifid nebula, M-20, at top and Lagoon nebula, M-8, at bottom (Brad Wallis); *M*: aurora, Sept. 29, 1978, seen from Sterling Heights, Mich. (Ondrej Michalec).

January Satellites of Jupiter
04:00 UT
(Avoid confusion! Read the UT conversion box below.)



1	01234
2	21034
3	20314
4	31024
5	34021
6	43210
7	403
8	40123
9	42103
10	42013
11	43102
12	34021
13	32140
14	014
15	10234
16	12034
17	20134
18	13024
19	30124
20	32104
21	23014
22	41023
23	4103
24	42013
25	41302
26	43012
27	43210
28	43201
29	41032
30	0143
31	2034

The four major satellites of Jupiter orbit the planet in periods ranging less than 2 days to 17 days. You'll see them change position from night to night. This table shows the approximate position of the moons each night. The column at the far left shows the date; the second column gives the names of the moons (Jupiter = 0, Io = I, Europa = 2, Ganymede = 3, Callisto = 4). The third column shows the satellites' positions as they appear through an inverting telescope; south is at the top.

Introducing Our New Planet Finder

On the facing page you'll see the result of some hard thinking on our part. We wanted to produce a new type of Planet Finder, which would offer all of our readers the best in information. Accordingly, we've redesigned it. We think you'll agree that it provides more information with less confusion!

Running along the left side is the familiar chart showing the positions of the sun and planets on the ecliptic, but the new version is easier to read — especially under dim light!

The right side has three sections. The top box is a new feature showing the positions of the planets in their orbits around the sun. The point of the vernal equinox, which is used as a zero point, is indicated by a short line. When the sun is seen to cross that line — that is, when Earth is *opposite* that line — spring begins in the northern hemisphere. All planets orbit in a counterclockwise direction as if seen from a point in space high above Earth's north pole. On the scale of the diagram it was impossible to show the orbits of Uranus, Neptune and Pluto; instead, their directions are indicated by short arrows.

The second box gives the planetary positions in right ascension and declination, epoch 1979. For the slower moving planets, we'll give only one position each month; for the faster ones, we'll show as many positions as necessary. The distance measure in astronomical units refers to the distance from Earth, not the sun.

The third box shows the telescopic appearance of the planets for the dates indicated. Where the date isn't given, the diagram shows the appearance at midmonth. South is at the top, to match the view through an inverting telescope.

Universal Time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.

degrees north of 4.5 magnitude Iota Librae, a close binary star system. The planet is now at 5.8 magnitude, and has a pale disk 3.6 seconds of arc across.

Neptune

At midmonth Neptune will be about 1-1/2 degrees west and 35 minutes of arc south of Xi Ophiuchi, a naked eye star which happens to be a binary with components of 4th and 8th magnitudes. To distinguish Neptune's appearance from an ordinary star, remember that you're looking for a tiny disk only 2-1/2 seconds of arc in diameter! Use a telescope and medium-high powers.

Pluto

On Jan. 22, Pluto will be closer to the sun than Neptune is on that date. The 14th magnitude speck of light is "racing" in toward perihelion which comes in early July 1989. The planet is now in north central Virgo.

Quadrantid Meteors

The Quadrantids are a homeless group of meteors, for the constellation from which they take their name no longer exists! In the dim area of sky between Hercules, Bootes and Draco, the astronomer Lalande placed Quadrans Muralis, the mural quadrant (a type of sighting device used formerly to make accurate determinations of stars' positions). The constellation, like the instrument, has passed into history, but the meteor shower's name persists!

The display peaks around Jan. 3, and this year the moon will be close to first quarter, leaving a dark sky for the meteors. During the early morning hours, you'll see more and more of them as the radiant point climbs higher above the horizon. You should expect to see about 40 per hour at maximum.

Photo Tips!

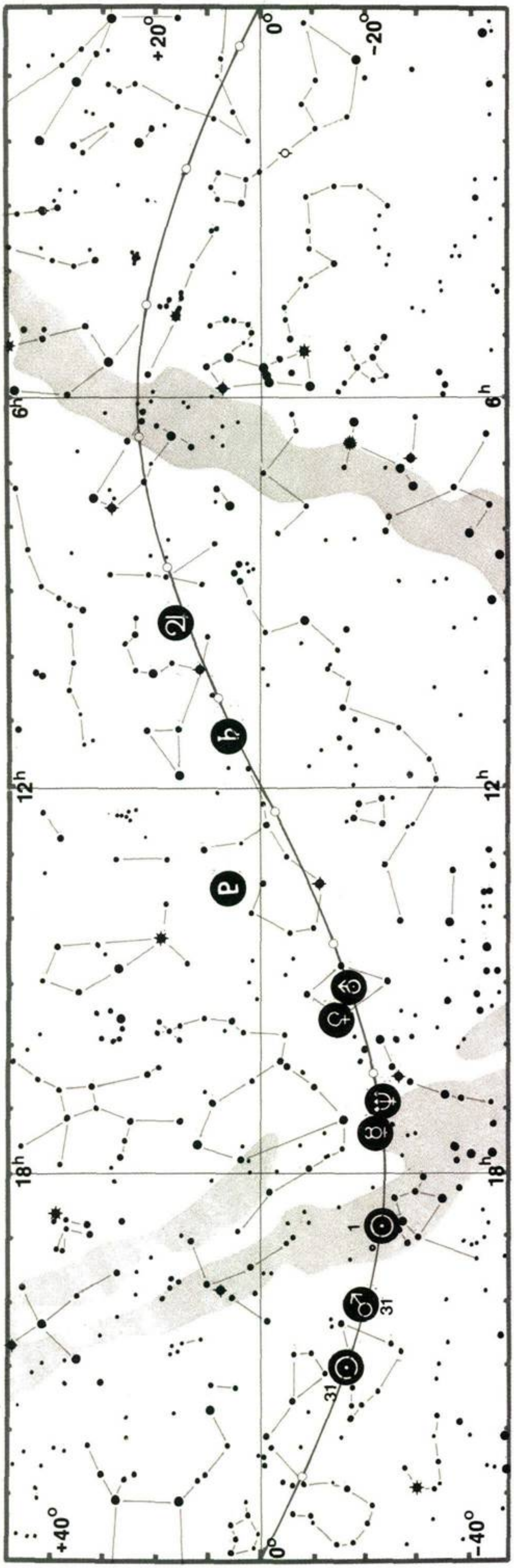
If you're planning to send us one or more of your latest photos, here are a few tips to remember:

1. Please send prints or slides only, no negatives!

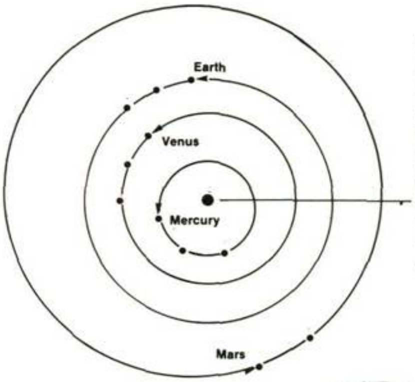
2. Don't send silk surfaced or textured papers — we can only use glossy.

3. Print your name and address on *each* item sent!

4. Send only your best ones!

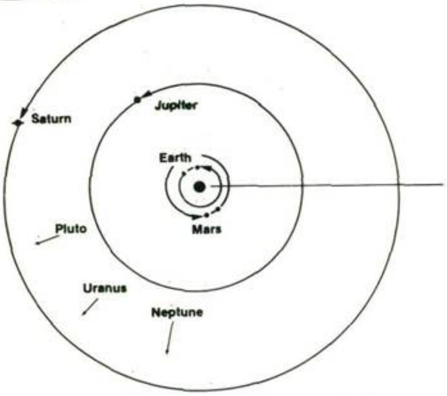

+20°
0°
-20°
6h
6h
12h
12h
18h
18h
1
31
31
+40°
0°
-40°

Planet Finder

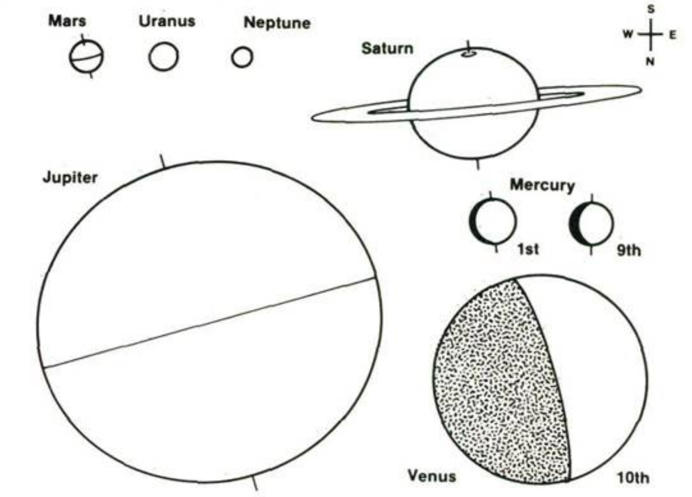

Earth
Venus
Mercury
Mars

The positions of Mercury, Venus, Earth and Mars in *their orbits are shown* for the beginning, middle and end of the month. (Mars for the beginning and end only). The vernal equinox is the line at right.

The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter *and Saturn for* mid-month. The outermost planets' directions are indicated.


Saturn
Jupiter
Earth
Mars
Pluto
Uranus
Neptune

Planet	Date	R.A.	Dec.	Mag.	Dist. (AU)
Mercury ☿	1	$17^h 13.0^m$	−21°53.9′	−0.2	1.15
	5	$17^h 36.0^m$	−22°46.8′	−0.2	1.22
	9	$18^h 00.4^m$	−23°25.4′	−0.3	1.27
Venus ♀	10	$16^h 05.1^m$	−16°57.9′	−4.2	0.61
	30	$17^h 30.3^m$	−20°08.1′	−4.0	0.76
Mars ♂	15	$19^h 50.9^m$	−22°01.1′	+1.4	2.39
Jupiter ♃	15	$8^h 31.3^m$	+19°32.8′	−2.2	4.30
Saturn ♄	15	$11^h 02.3^m$	+8°14.2′	+0.8	8.64
Uranus ⛢	15	$15^h 11.6^m$	−17°29.3′	5.7	19.08
Neptune Ψ	15	$17^h 13.9^m$	−21°37.8′	7.7	31.08
Pluto ♇	15	$13^h 35.5^m$	+8°32.2′	14.0	30.12


Mars
Uranus
Neptune
Saturn
S
W
E
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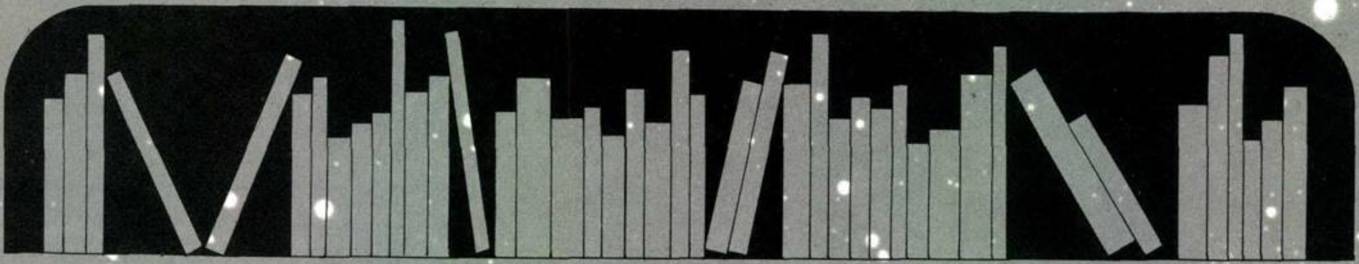
Jupiter
Mercury
1st
9th
Venus
10th



ASTRONOMY REVIEWS

Ten Faces of the Universe

by SIR FRED HOYLE

206 pages (illus.), paperback, $6.95
W.H. Freeman (1977)

The more knowledge a reader brings to this latest book by Fred Hoyle, the more he or she will gain from it. It's so engagingly written that someone with virtually no astronomical background can enjoy learning a great deal. But Hoyle's easy prose also addresses some deceptively advanced and breathtaking concepts.

The title refers to 10 different aspects of the universe that different groups of people study and perceive. Each of the "faces" is treated in a separate chapter with titles like "God's Universe", "The Physicist's Universe", "The Expanding Universe", etc. In spite of these divisions, the subject matter of each chapter is not completely self-contained within the boundaries of its name; just as in reality the different aspects of the universe blend together, so the subject matter of the different chapters overlap.

In several chapters Hoyle outlines the history of the development of certain concepts. For example, in "The Mathematician's Universe", he describes the history of the concept of subatomic interactions from James Clerk Maxwell through Enrico Fermi. In other chapters he concisely summarizes present day views of the universe, including detailed discussions of such wide-ranging topics as world lines in spacetime, atomic structure, interactions and forces, plate tectonics, religious philosophy, the origin of life and the fate of humanity.

Through all these discussions, Hoyle allows his — and others' — imagination free rein to speculate on all manner of provocative issues. In "Nobody's Universe" he discusses the hypothesis of John Wheeler and Richard Feynman that the universe "responds" to time-symmetric physical laws, and thus creates cause and effect, preventing the future from affecting the past.

In "The Origin of the Universe", he then addresses the knotty, complex possibility that what we see as the universe may be only one tiny portion of a universe that's far vaster than presently conceived. This chapter is one of the most difficult to follow, even though the language is nonmathematical, because so many of the ideas totally counter intuition.

The climax of the book is the last chapter, "Everyman's Universe", in which he expounds his own fundamental pessimism about the future of humanity — his own lack of faith in tomorrow.

Because the contents are so much his personal views, you cannot categorically state whether he is right or wrong. You can, however, disagree with him — and many readers will. In connection with his last chapter (on humanity's future), you can convincingly argue that pessimism is cheap. It's seductively easy to contend that we're just the passive victims of historical trends, instead of facing the fact that people create those trends! To solve problems and take control of the future requires unremitting dedicated labor — but hard work against uncertain odds seems a lot less attractive than simply giving up. Hoyle may be right, but in the meantime, inculcating people with apathetic pessimism seems the surest way to bring on the disaster.

Whether you agree or disagree, the book *is* thought provoking, and should generate a lot of discussion. *Trudy E. Bell.*

◆

Binary and Multiple Systems of Stars

by ALAN H. BATTEN

278 pages (illus.), hardcover, $18.50
Pergamon Press (1973)

Binary stars were once viewed as a somewhat dull but necessary subtopic of astronomy. Astronomy courses used to describe the time-consuming calculations required to deduce orbits, and teachers required memorization of the list of basic stellar properties, such as stellar mass and diameter, that can be learned under certain conditions from binary orbits. Binaries were so under-appreciated that many people assumed they were an oddball minority among stars. Today, astronomers see growing evidence that most seemingly single stars of the night (perhaps 50 to 95%) have one or more companions in orbit around them. Furthermore, as we learn about the physics of these objects, we find that many are truly extraordinary. Some of the sky's most interesting objects, such as supernovae and X-ray sources, are turning out to be intimately involved with binary star systems in which gas shot out of one star is being dumped into the other. Also, binaries are coming under increasing scrutiny as researchers ask whether planet systems may be simply low mass examples of binary or multiple star systems.

In spite of these exciting aspects of binary stars, few introductory or technical books deal with them. This work explains many of their properties and is probably the best general introduction to the subject at a moderately technical level. It summarizes much of the work that has led to current interest in binaries, including Zdenek Kopal's early reorganization of the classification system away from observational and orbital properties such as binaries visible through a telescope, binaries detected only by spectroscopic data, wide binaries, close binaries, etc. This has led toward a classification based on physical and evolutionary properties (binaries with no interaction, binaries where one member has evolved and expanded enough to dump gas on the other, and binaries where both have evolved and expanded enough to be in contact with each other).

Chapters include topics such as "Basic Concepts...", "The Incidence of Binary Systems", "Multiple Star Systems" and "Evolution and Origin of Binary Systems". There are also chapters on more technical aspects of binary star analysis. The book is well-suited to researchers, students or advanced observers who want to learn about astrophysical problems and properties of binaries and multiples. There are some mathematical discussions and 15 pages of bibliography. The book is not suited to casual beginners. For example, there are no tables of easily observable doubles, though there are interesting references to many specific systems.

The only problem with this excellent book is that it is now five years old, and new work accumulates quickly in modern astronomy. For instance, while Helmut Abt's early studies of the incidence of binaries is described, Abt now has new data and new considerations on the incidence of low mass companions that have not been included. Nevertheless, this is an excellent reference volume for anyone interested in the growing implications of the fact that most stars have companions on their journeys through time and space. *William K. Hartmann*

◆

The Red Limit
by TIMOTHY FERRIS

287 pages (illus.), hardcover, $10.00
William Morrow and Co., Inc. (1977)

Where's the edge of the universe? How did the universe begin? Will it expand forever? These are just a few of the questions Ferris tackles in this delightful and informative book. Although directed at a lay audience, it would be enjoyed by anyone interested in cosmology.

The approach is basically historical, and much of the charm of the book comes from his extensive use of anecdotes and quotes. In researching the book, Ferris interviewed over 20 astronomers and physicists (including Allan Sandage, Geoffrey Burbidge, Jesse Greenstein and Maarten Schmidt); many of them are quoted, and the writing overall is excellent.

There are relatively few errors, though some are present. Ferris refers to the 263 inch Soviet reflector, when the actual size is 236 inches. And he states that the Cavendish laboratory is at Oxford; it is, of course, at Cambridge.

The book begins with a history of the discovery of the expansion of the universe, centered around Shapley, Hubble and Humason. There's a detailed discussion of the famous Curtis–Shapley debate. Some of the statements Ferris makes regarding it may stir a little controversy, but in this case it's hard not to.

Chapter two, "Why Is the Sky Dark at Night?", is one of the weaker spots of the book. It is only 3-1/2 pages long and doesn't do justice to the problem. In addition, Ferris states that the paradox has now been resolved with the discovery of the expansion of the universe. E. R. Harrison of the University of Massachusetts has recently written several articles contradicting this. Why don't we see a bright night sky? Harrison says, "The universe just doesn't contain enough energy." Even if we converted all the matter in the universe to starlight, there wouldn't be enough. According to Harrison most of the light that would give us this bright sky comes from very distant points of the universe. And if we look into these distant regions we are, of course, looking back in time. We're therefore seeing younger and younger stars, until finally we see no stars at all.

According to Ferris' explanation, the more distant a galaxy is, the redder its light. Eventually the dropoff is so great the light never reaches us. Harrison has shown, however, that the dropoff rate is not great enough.

You'll find a particularly interesting account of the discovery of the four degree Kelvin background radiation. Most authors treat this in a straightforward way by stating that Dicke predicted the radiation (Gamow had actually predicted it several years before him) and then began looking for it. News soon reached Dicke that a strange type of radiation had been discovered by Penzias and Wilson at Bell Laboratories and, of course, the radiation turned out to be exactly what he was looking for. Ferris relates this story by telling how disturbed Penzias and Wilson were by the excess radiation — before they knew what it was. They took their radio telescope apart looking for something causing it. All they found were two pigeons nesting in it, so they sent them back to Bell Laboratories, their employers. Naturally, they were homing pigeons and came back again in a few days!

Chapter eight carries the same title as the book, and contains an excellent account of Maarten Schmidt's struggle with the spectra of quasars. According to Ferris, after finally resolving the problem, Schmidt drove home and told his wife "Something horrible happened at the office today." Seeing how shocked she looked, he suddenly realized he had chosen the wrong word. "I mean something wonderful," he said.

Many of the book's 26 photographs have appeared before in other books, but some are new. The ones of astronomers are excellent. There's an extensive bibliography in the back, divided into textbooks, basic books on astronomy, advanced and technical books, relativity, cosmology, philosophy and journals. (Some of the more recent books are missing from his list.) Finally, there is a glossary.

In summary, the book is an outstanding account of cosmology written with grace and charm. It is strongly recommended. *Barry Parker.*

◆

Our Changing Universe: The New Astronomy
by JOHN GRIBBIN

160 pages (illus.), hardcover, $9.90
Macmillan London Ltd. (1976)

Astronomy, the oldest of the sciences, is also one of the newest. In the past 15 years dramatic new discoveries have been made — quasars, pulsars, black holes, polyatomic molecules, the cosmic microwave background, to name just a few — that have changed the face of astronomy. With the past five or six years many excellent new introductory textbooks have appeared, but there is still a dearth of books on this "new astronomy" for the armchair reader.

Gribbin's book is an attempt to fill that gap. It consists of 16 chapters on such diverse topics as radio astronomy, quasars, pulsars, the Crab nebula, molecules in space, cosmic rays, the solar neutrino puzzle, x-ray astronomy, black holes and white holes, gravitational radiation, the cosmic background radiation, cosmology, spacecraft and planets, as well as an appendix that attempts to explain one theory of the Ice Ages.

To cover all these topics to a layman's satisfaction would require a Renaissance Man. Unfortunately, Gribbin isn't that man.

The emphasis throughout is on British contributions to the new astronomy. This is understandable, for Gribbin is English, and the book was originally published in England. Gribbin's analogies may be hard for an American reader to follow, as when he describes x-ray emission as coming from a mound of gas "about as high as the Post Office Tower and covering an area nearly as big as Hyde Park". Often his chauvinism is amusing and harmless, as when he mentions that the "latest" atomic clocks are Britain's cesium or rubidium resonators, and not the hydrogen masers of the U. S. Naval Observatory which are hundreds of times more accurate.

But the emphasis on English astronomy sometimes gives the reader a distorted picture. For example, when Gribbin goes into the history of radio astronomy, the only non-English name he mentions is Karl Jansky. Perhaps his neglect of the contributions of Grote Reber, Jan Oort, H. C. van de Hulst, Edward Purcell, and other non-British pioneers in the field is counteracted by the overblown statement that "Jansky's immediate recognition of the importance of his discovery ranks with Newton's realization that something important could be learned by watching an apple fall".

A more serious example of distortion occurs in the chapter on black holes and white holes. Gribbin says, "Although the periodic variations of Cyg X-1 tell us that there must be more than one star in the system, *there is nothing which indicates that there can be only two stars there*" (author's italics). He goes on to say (correctly) that if there are three stars instead of two in the system, then Cygnus X-1 can be explained without invoking black holes at all. To clinch the matter, he cites Occam's razor: If two explanations can both account for the same effect, then the simplest explanation is probably correct. And there he leaves the reader. What Gribbin does not say is that exhaustive searches by astronomers all over the world have failed to turn up any evidence for a third component of the Cygnus X-1 system!

Even in fields where Gribbin could give us new insights, he fails to do so. An example is the chapter on pulsars. In his opening paragraph Gribbin tells us he was a graduate student at Cambridge University in 1967. Readers may already know that it was at Cambridge, in 1967, that Jocelyn Bell first noticed the persistent, periodic "fuzz" in a radio spectrum and reported it to her superior, Anthony Hewish. Hewish worked out the correct interpretation, coined the word "pulsar", and later received the Nobel Prize for his work. Gribbin was in the right place at the right time to give us first hand information on this historic event. But the names of Bell and Hewish are not even mentioned, nor is their work described.

Gribbin's book is profusely illustrated — in fact, 51 of the 151 text pages are full page illustrations, and another 20 pages or so contain half page illustrations. To cover 17 widely diverse topics in less than 100 pages of text, one cannot go into great detail — but the information that *is* given should be accurate. Gribbin gives the density of Mercury as eight grams per cubic centimeter (it is 5.4); the sun's orbital period around the galaxy as 500 million years instead of 250 million years, and apparently uses an obsolete value of the Hubble constant in deriving his distance to Cygnus A!

Our Changing Universe is shallow, misleading and inaccurate. Most of the topics discussed have been covered in greater depth and with greater accuracy by the lead articles in ASTRONOMY. *Jeanne Hopkins.*

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NEW ASTRO-BOOKS

Galileo at Work
by STILLMAN DRAKE

536 pages, hardcover, $25.00
University of Chicago (1978)

A year-by-year biography of Galileo emphasizing his lesser known scientific work has been written by one of the world's foremost "Galileo experts". The work has English translations of many items hitherto untranslated.

Asteroids: An Exploration Assessment
edited by D. MORRISON and W.C. WELLS

300 pages, paperback, $11.75*
NASA (1978)

This book, NASA Conference Publication 2053, is the record of a workshop on asteroids held at the University of Chicago in January 1978. The four parts of the book examine the relationships between meteorites and asteroids, current observational knowledge of asteroids, the possibilities of missions to asteroids and, lastly, the sorts of observations needed for further progress. This is a detailed and largely technical examination of where we now stand in our knowledge of minor planets and related objects in the solar system.

**For sale by NTIS, Springfield, Va. 22161.*

Stars: Their Birth, Life and Death
by IOSIF S. SHKLOVSKII

442 pages (illus.), hardcover, $17.50
W.H. Freeman (1978)

A renowned Soviet astrophysicist surveys stellar evolution in detail for the educated layman. This is an English translation of the original Russian edition which was published in 1975.

Murmurs of Earth
by CARL SAGAN et al.

275 pages (illus.), hardcover, $15.00
Random House (1978)

Voyagers 1 and 2 were each sent off from Earth with a load of instruments — and an LP record! The record contains typical sounds and music from many cultures on Earth, and 120 photographs (recorded by a special technique). The "authors" of the record here describe what was chosen, how and why.

Space Art
compiled by RON MILLER

192 pages (illus.), paperback, $7.95
Starlog (1978)

There are many artists who practice, exclusively or not, "space art" — a subject familiar to all readers of this magazine. In this book are many examples of the genre, only one of which has appeared in ASTRONOMY.

In Search of Ancient Astronomies
edited by E. C. KRUPP

300 pages (illus.), hardcover, $10.00
Doubleday & Company, Inc. (1978)

The director of the Griffith Observatory in Los Angeles edited this book of seven chapters examining primitive or prehistoric astronomical systems and structures. The emphasis is on Europe and the Americas.

The New Astronomy
by PAUL and LESLEY MURDIN

215 pages, hardcover, $12.95
Thomas Y. Crowell Company (1978)

This is a nontechnical account of what's been learned in recent decades about supernovae, pulsars and black holes, centering primarily on studies of the Crab nebula.

Atlas of Mercury
by M. E. DAVIES et al.

128 pages, hardcover, $6.00
NASA (1978)

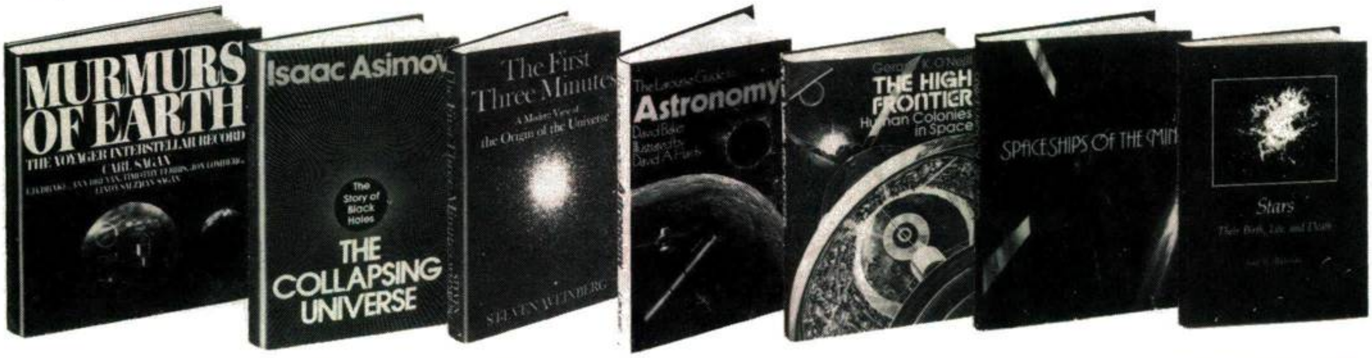
In three passes by Mercury, Mariner 10 provided us with a look at 1/2 the planet's surface. This book presents about 150 beautifully printed photographs, both individual images of great detail and computer generated mosaics covering large areas of the surface. Data on the planet and spacecraft are also given. It's NASA SP-423 (or stock number 033-000-00695-1 at any U. S. Government Printing Office bookstore)

Structure and Properties of Nearby Galaxies
edited by E. M. BERKHUIJSEN and R. WIELEBINSKI

307 pages (illus.), hardcover, $38.00; paperback, $24.50
D. Reidel Publishing Company (1978)

The proceedings of an IAU symposium held in August 1977. Highly technical.

The birth and evolution of the universe... colonies in space... celestial masers... the physics of the planet earth... black holes, quasars, and the universe...



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THE IMPORTANCE OF APERTURE

Classical refractor, Newtonian reflector, Maksutov, Schmidt-Cassegrain—is there an optical configuration of unequivocal superiority? With every vendor proclaiming the merits of his own particular design, it is all too easy to overlook several truisms from veteran telescope users:

(a) All designs can perform satisfactorily if properly and responsibly made.
(b) Each design has its own special virtues.
(c) Far more significant to performance than any aspect of a telescope's *design* is its clear *aperture*.

On the last of these points, optical theory firmly establishes the limits of light grasp and resolution for a given aperture. In brief:

(a) Resolution is a direct function of aperture.
(b) Light grasp is proportional to the square of aperture.
(c) Airy-disc brilliance (the brightness of a point-source steller image) is proportional to the fourth power of aperture.

When you double the aperture of a telescope, you increase its resolving power by a factor of two and boost its light-gathering power by a factor of four. But more importantly, you also reduce the area of the Airy-disc by a factor of four. This results in a 16-fold gain in image brilliance.

For example, with a four-inch telescope at 150x, a globular cluster such as M-13 is totally amorphous—no matter how good the seeing conditions might be. With an eight-inch telescope at the same power, the stars are separated twice as well, are 16 times more brilliant and the cluster is resolved to the core—even during periods of poor seeing.

The same general principle applies when viewing the detailed structure of planets, nebulae and galaxies. When you increase the aperture of a telescope, you dramatically increase the amount of visible detail and contrast.

Assuming quality optics, it makes little difference whether the comparison telescopes are refractors, reflectors, or catadioptrics.

Thus, we look askance upon the claims of any supplier of small refractors or catadioptrics who implies that his instrument, because of its type, will outperform substantially larger telescopes of different design. The larger aperture always excels, and any advertiser who suggests otherwise is in need of a high school physics refresher or an evening at a star party where different type telescopes of varying sizes may be directly compared.

Frequently, these same suppliers claim their smaller instruments can split the closest doubles and reveal the smallest planetary detail with greater ease than larger professional telescopes.

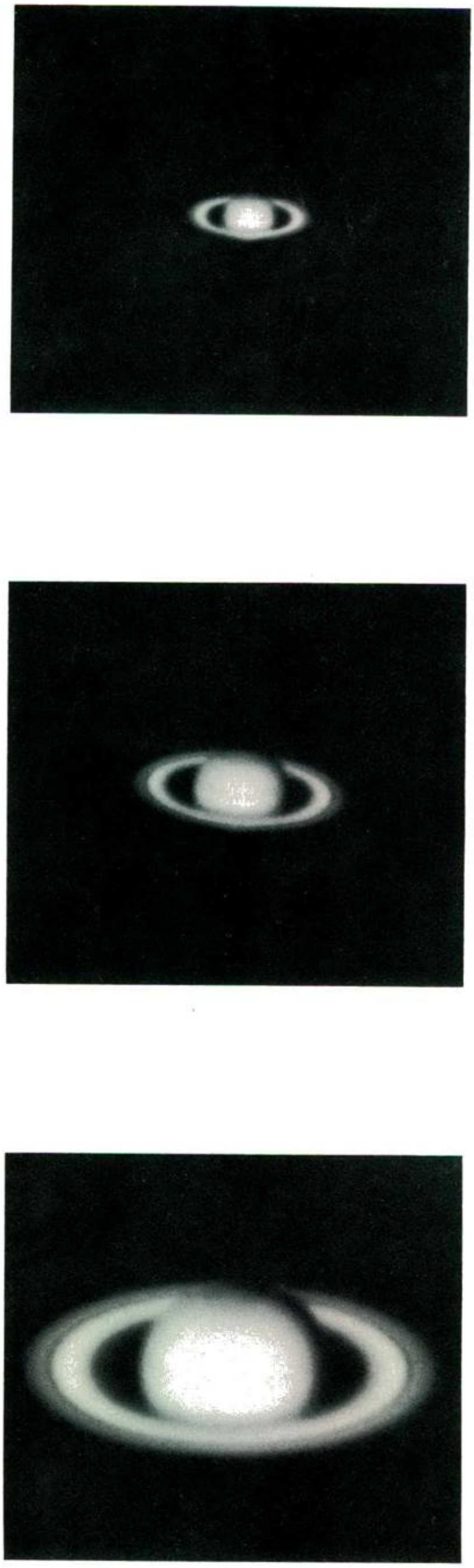
The basis of their argument is that atmospheric scintillation will not permit the larger telescopes to achieve the resolution their larger apertures make possible. When turbulence is great, they argue, a four-inch telescope will show the same amount of planetary detail that is visible through the Mt. Wilson 100-inch reflector or the Lick 36-inch refractor, for example, under the same conditions.

In deference to the professional astronomers who have used such large-aperture telescopes to spectacularly probe the universe for the last half-century, we wish to correct this fallacy.

On nights of gross turbulence, we can see (within our own product line) that, at high magnification, the C5 will sometimes render a superficially steadier view of some bright objects than the C8 or C14, though this is *never* the case with low-contrast subjects such as nebulae and star clusters. What this really indicates is that the smaller instrument is incapable of resolving the more subtle aspects of turbulence to the extent of the larger. The same effect may be achieved by lowering the magnification of the larger instrument so that turbulence remains unresolved, and you'll still enjoy the benefits of substantial aperture—much greater image contrast and brilliance. Those of us who use large-aperture telescopes live for those not-so-rare evenings when the air steadies sufficiently to use our instruments for views that no small telescope can ever equal.

The simple truth is: At any given magnification, the larger the aperture of the telescope, the better the image will be.

Our C90 telescope is an excellent choice for the beginning amateur astronomer or for one who demands the utmost in portability. Considering the continually rising prices of poor quality, imported telescopes and the very high prices of some domestic catadioptrics, the C90 is, perhaps, the best telescope buy in the world. And if your astronomical involvement is already of serious proportions, we strongly urge you to consider our larger aperture telescopes—whose capabilities will provide a lifetime of observing enjoyment.



Above: a dramatic illustration that visible detail and brilliance increase with telescope aperture. From top to bottom, a 5-inch, an 8-inch and a 14-inch telescope reveal Saturn's structure on film with increasing resolution and contrast. The effect is even more pronounced during visual observation.

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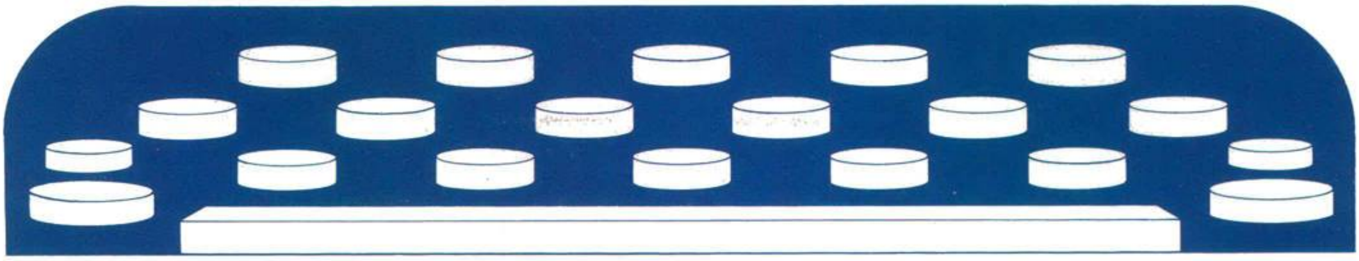


Sir / I have a question: We know what an eclipse of the sun looks like from Earth, but what would it look like if you were somewhere in space and saw the sun blotted out by Earth?
BRETT MILLER
Richmond, Va.

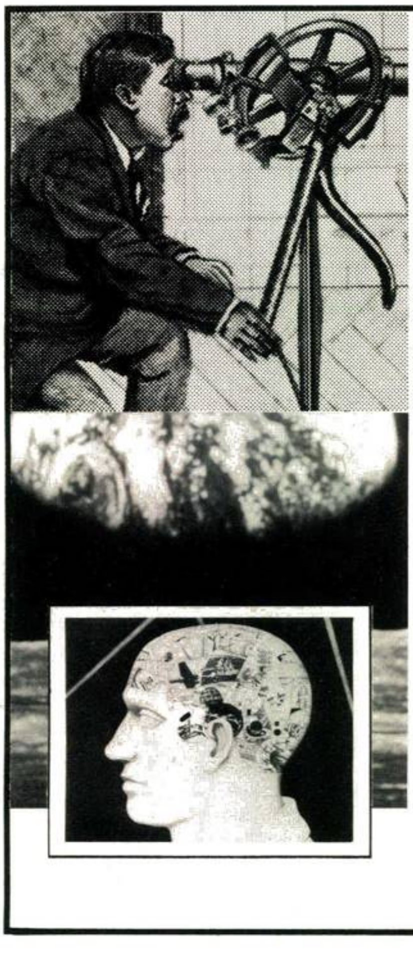
Mr. Miller / What you're asking about isn't a purely hypothetical matter, because just such an event has been seen! On their return to Earth, the crew of Apollo 12 flew into the cone of Earth's shadow, and saw the sun eclipsed. Earth was a black disk surrounded by the bright, multicolored ring of the backlit atmosphere. Away from the edge of Earth extended the tendrils of the sun's corona. Of course, Earth appeared far larger than the sun did, so the eclipse was really total!

Sir / When observing meteors I have found a light colored 12 inch ruler to be more useful than white string (as mentioned on page 31 of the August 1978 issue) to establish quickly the path of a just-seen meteor against background stars.

String requires two hands. A ruler, or even a light colored stick or similar piece of wood, can be held against the sky with one hand while notes can be made with the other. The light color, of course, makes the ruler or stick more easily visible against a dark sky.

Some observers may find a 12 inch ruler too short for some meteors. If so, a yardstick works just as well.
E. RAY GRASSHOFF
Schulenburg, Tex.

Sir / I am writing on behalf of a citizens' group formed to cope with the anticipated visit of many interested viewers of the total solar eclipse. Although much of southern Manitoba lies within the path of totality, the center line is where the total eclipse



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will last the longest. Arborg, Manitoba is right on the center line and expects totality to last 2 minutes 47 seconds. Our hotel and motels have been booked up since last June, but our committee has set up a billetting system, and we are ready and willing to accommodate a great number of people who may be interested in coming to our community for this great event. Our mailing address is: Arborg Solar Eclipse Committee, Arborg, Manitoba R0C 0A0, Canada. Inquiries will be answered promptly.

CAROL AITKEN
Arborg, Manitoba

Sir / I own a small (4-1/4 inch) Newtonian reflector that I wish to use for astrophotography. I purchased a combination first-focus eyepiece projection camera-to-telescope adapter and discovered that I could not get a focused image to my camera using either one of these methods. In an article in ASTRONOMY, May 1975, it explains that a remedy for this situation would be to increase the effective focal length by moving the main mirror cell forward in the body tube so that a focused image could reach the camera. On my telescope, however, the mirror cell is fixed in place and the only way to move it would be to cut off part of the body tube and remount the mirror. The consequence would be that I would never be able to observe through the eyepiece again. I hope you can help me find some alternative or solution to my problem.

MICHAEL CORBIN
Reseda, Calif.

Mr. Corbin / You can engage in astrophotography and visual observing if you move your mirror forward just enough (and no more than is necessary) to bring the image to the camera film plane. Eyepieces will then focus rather far out, but not so far that visual observing is impossible.

Another alternative is to do all of your astrophotography through a Barlow lens. The Barlow will move the focal plane farther outside the telescope tube than it previously was. The disadvantage is that focal ratio is larger and the image dimmer, the advantage is that you need not modify the telescope itself.

Sir / I enjoyed the "The Redshift Problem" by Barry Parker (September 1978). Before reading this article I thought the Doppler effect was the only explanation for the large redshift in quasars, but now I see there are some problems with it. Is it possible that this large redshift is caused by an extremely strong gravitational field, or a combination of both Doppler and gravitational redshifts?

WATARU EBIHARA
Strongsville, Ohio

Mr. Ebihara / Most astrophysicists agree that an Einstein gravitational shift cannot satisfactorily explain the redshifts of quasars, although there are a few holdouts. Fred Hoyle was the first to propose this explanation back when the large redshifts were first discovered, but since then no one has been able to work out a reasonable physical model which fits the observational evidence — not even the highly imaginative and creative Hoyle himself. A growing minority of astrophysicists, such as Victor Clube, believe that a radically new physics is necessary to explain quasars and some other recent astronomical mysteries. They feel we are presently hovering on the verge of a new scientific revolution comparable to those of Copernicus, Newton and Einstein. The next few years may see astronomy becoming a more exciting field than ever!

Sir / If a photon has any mass at all, then according to relativity theory its mass must be infinite. Any object with mass which moves at light speed must possess an infinite mass at that speed. But if, on the other hand, a photon has no mass, then how could it possibly be deflected by a gravitational field?

TERRY L. HULSE
Fullerton, Calif.

Mr. Hulse / A photon, indeed, has zero mass, and according to modern physics, a massless particle such as the photon (or a neutrino) must move at the speed of light and can never slow down at all. It is impossible to get a photon or neutrino to come to rest — they have to be "on the move" all the time. But photons are deflected in gravitaional fields not because of any mass, but because, according to Einstein's General Theory of Relativity, the space-time itself is curved around any mass. The photon "thinks" it's following a straight line — which is actually curved. It was precisely the confirmation of this surprising prediction that a massless particle would be curved by a gravitaional field, in an eclipse observation in 1919, that demonstrated the accuracy of Einstein's new theory.

Sir / The Astronomical League's Light Pollution Committee is sponsoring a photography contest — with light pollution as its theme. There are two purposes for this contest: One is to achieve public awareness and involvement, and the other is to build a resource of photographic illustrations of problems and solutions to light pollution.

The problem does have solutions, and they are available now. The lighting industry is familiar with the problems, and has ready solutions to many. That much can be seen by glancing through nearly any catalog of municipal lighting equipment! Our major tasks are to identify which types of light sources are least destructive, and to create a broad enough reason to justify the real and considerable costs of change. We seek to make the cost of NOT changing too great for our politicians to bear, by forming a broad based coalition extending beyond the bounds of astronomy.

The contest rules are simple, and anyone may enter. A donation of $1 per entry is needed to defray mailing costs. Prizes will be awarded at the Portland convention of the Astronomical League in August 1979. You may submit entries until June 1, 1979. Each month, the League will send some of the best entries to ASTRONOMY and other magazines, and the winning pictures will be widely distributed. To receive an entry form and rules, send your donation to:

Astronomical League
LPC Contest Manager
935 Orange Ave.
Winter Park, FL 32789

Editor's Note: We're sure many of our readers will want to help the Astronomical League and its fight against light pollution. And, of course, we at ASTRONOMY will try to bring you some of those winning submissions.

Sir / Would you please supply me with the exposure times, films, filters and instruments used to take the Milky Way photographs published in your September 1978 issue, pages 18 through 29?

MARK WAGNER
Chicago, Ill.

Mr. Wagner / Certainly! Many readers asked, so here goes: the Lagoon nebula by Greg Griffith, 12 inch f/4.5 Newtonian, four 10-1/2 minute exposures on 103aE integrated together; Lagoon and Trifid nebulae by Dennis Stayer, no technical information; the Large Magellanic Cloud by Ronald Royer, four inch f/5 astrographic camera, tricolor composite (we'll explain this technique in a future article); Milky Way by James Janesick, 50mm f/2 lens, Ektachrome 200 film, 35 minute exposure; Omega Centauri by Ben Mayer, Celestron 14 at f/7.5, Ektachrome 200 in a cold camera for 90 minutes; Scutum starcloud by Richard Berry, Aero Tessar four inch f/6 lens, 20 minutes on 103aF plate; Ophiuchus dark nebula by J. A. Farrell, 7.5 inch f/3 Schmidt camera, 103aE with #29 filter for 15 minutes; Cocoon nebula by Greg Griffith, same as above; Cygnus Loop by Robert Flory, 300mm telephoto f/2.5, 103aF with a #29 filter for 20 minutes; Gamma Cygni region by Chris Bowland, Celestron five inch Schmidt, 103aF with a #29 filter for 30 minutes; wide angle Milky Way by Gordon Solberg shot through a backward finderscope, 30 minutes on Tri-X; North America nebula by Howard McCallon, 50mm f/2.8 lens, 103aE with a #92 filter for 30 minutes; the Pelican nebula by Walter Hamler, eight inch f/5 Newtonian, 45 minutes on 103aF; North America nebula by William Hamler, as above, for 12 minutes; Pleiades by Frank Melsheimer, eight inch f/3 Schmidt camera, 103aF for 15 minutes; Auriga by J. A. Farrell, as above; California nebula by David Healy, 135mm f/2.5 telephoto lens, 103aE with a #29 filter for 15 minutes; Orion nebula, by Howard McCallon, 12 inch f/5.6 Newtonian, Fuji R-100 for 22 minutes; Crux by Ronald Royer, tricolor composite (see above); Rift in Aquila by Richard Berry, 28mm f/2.8 lens, Tri-X for 40 minutes.

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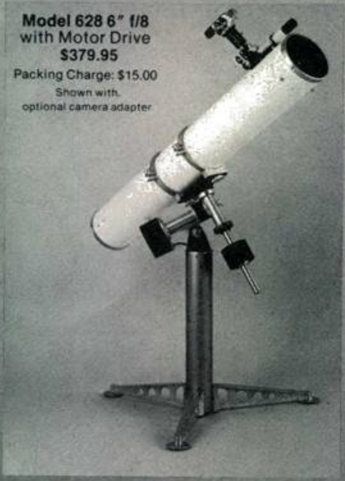

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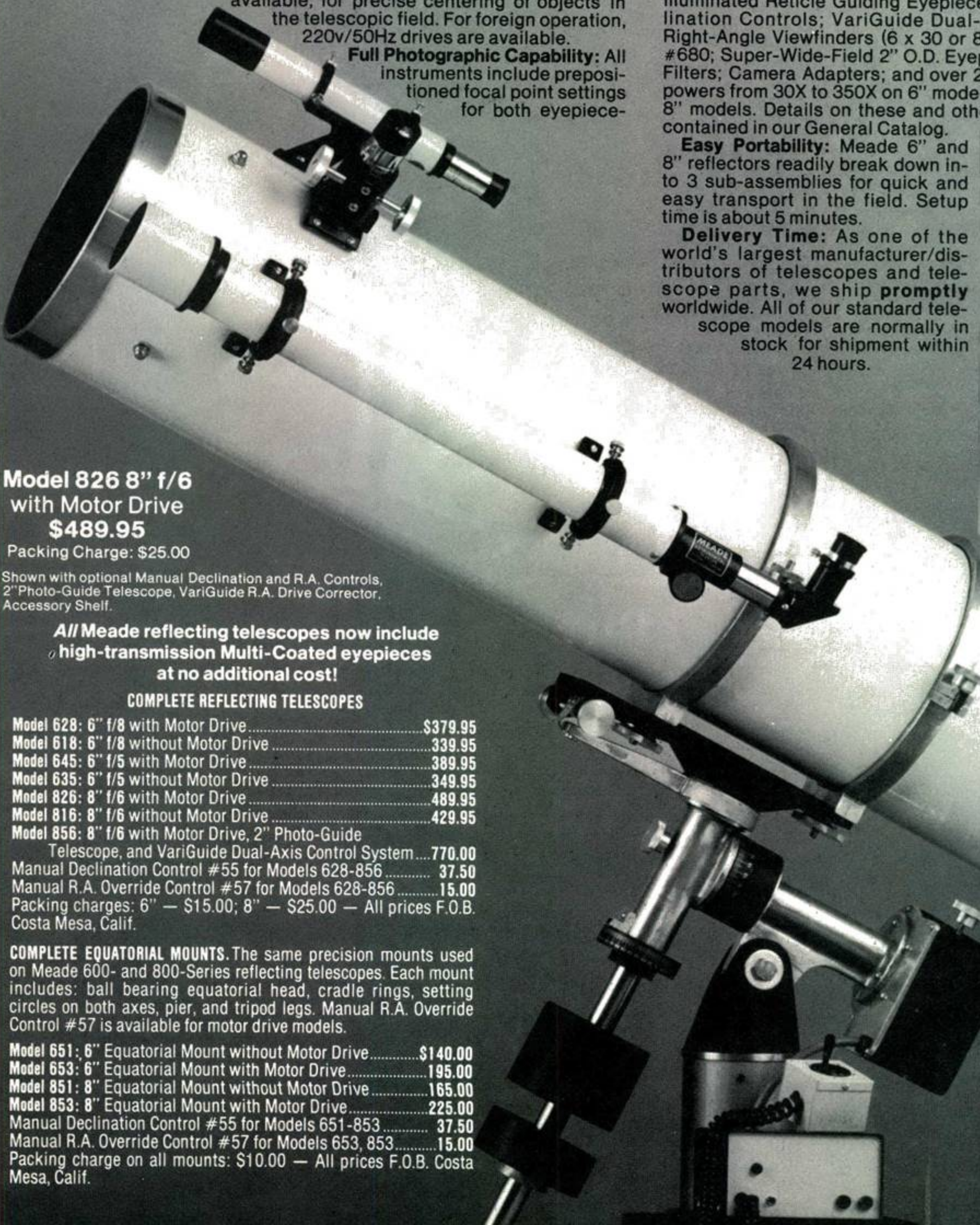

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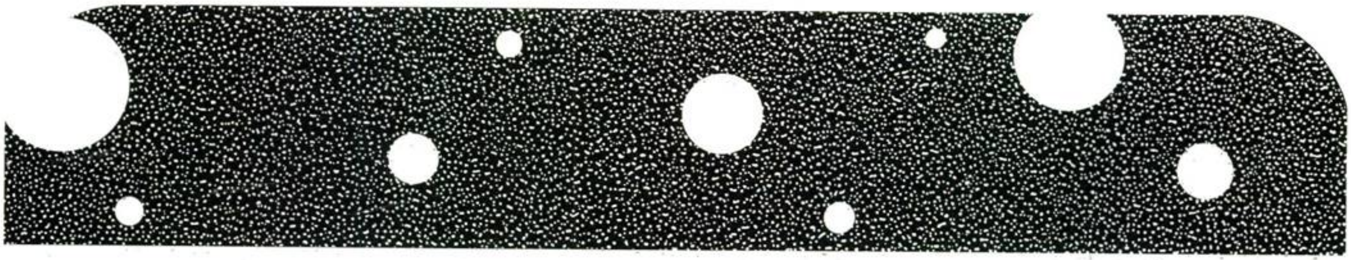
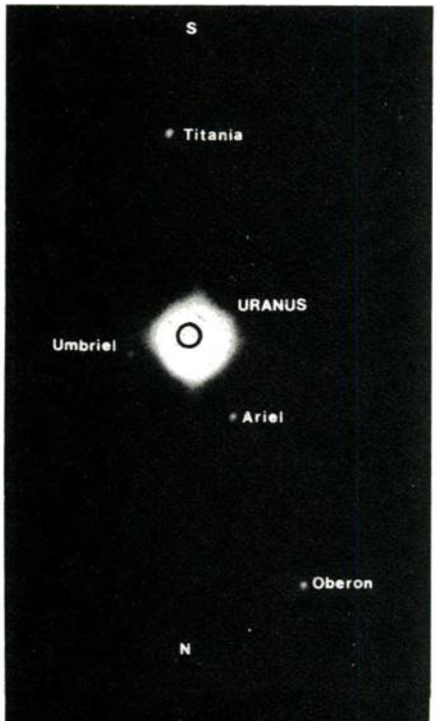


STELLAR FRONTIERS

Herschel and the Rings of Uranus

by
Charles F. Capen

Friedrich Wilhelm Herschel, perhaps the greatest of all amateur astronomers, set himself the stupendous task of a systematic survey of the entire heavens that was within reach of his favorite Newtonian reflecting telescope. Herschel's scope had a polished metal mirror of his own invention, with an aperture of 6.2 inches and a focal length of 84 inches. His plan was to observe every visible object, and describe its appearance and position on the celestial sphere.



This photo of Uranus taken on March 8, 1972 shows four of its five known satellites. Miranda, the fifth, orbits very close to the planet and is difficult to photograph or even to observe directly because of the brightness of the disk. The small black circle shows the true apparent size of Uranus at the time of the photograph, much smaller than the recorded image! The difficulty in observing the dim, narrow rings close to the body of the planet is obvious. Photograph courtesy of New Mexico State University Observatory.

While thus engaged on the evening of March 13, 1781, he came upon a curious object that seemed larger than the fixed stars. Herschel knew the apparent diameter of the stars remained as points of light when higher telescopic powers were employed, while nearby solar system objects increased their sizes in proportion to the magnifying power used. When he applied this test to his new celestial object, increasing powers from his usual 227 to 460 and 932, it showed larger disk diameters in each case. The highest power magnified it so much that it became dim and ill-defined. Herschel thought he had found a nebulous type of star or perhaps a comet.

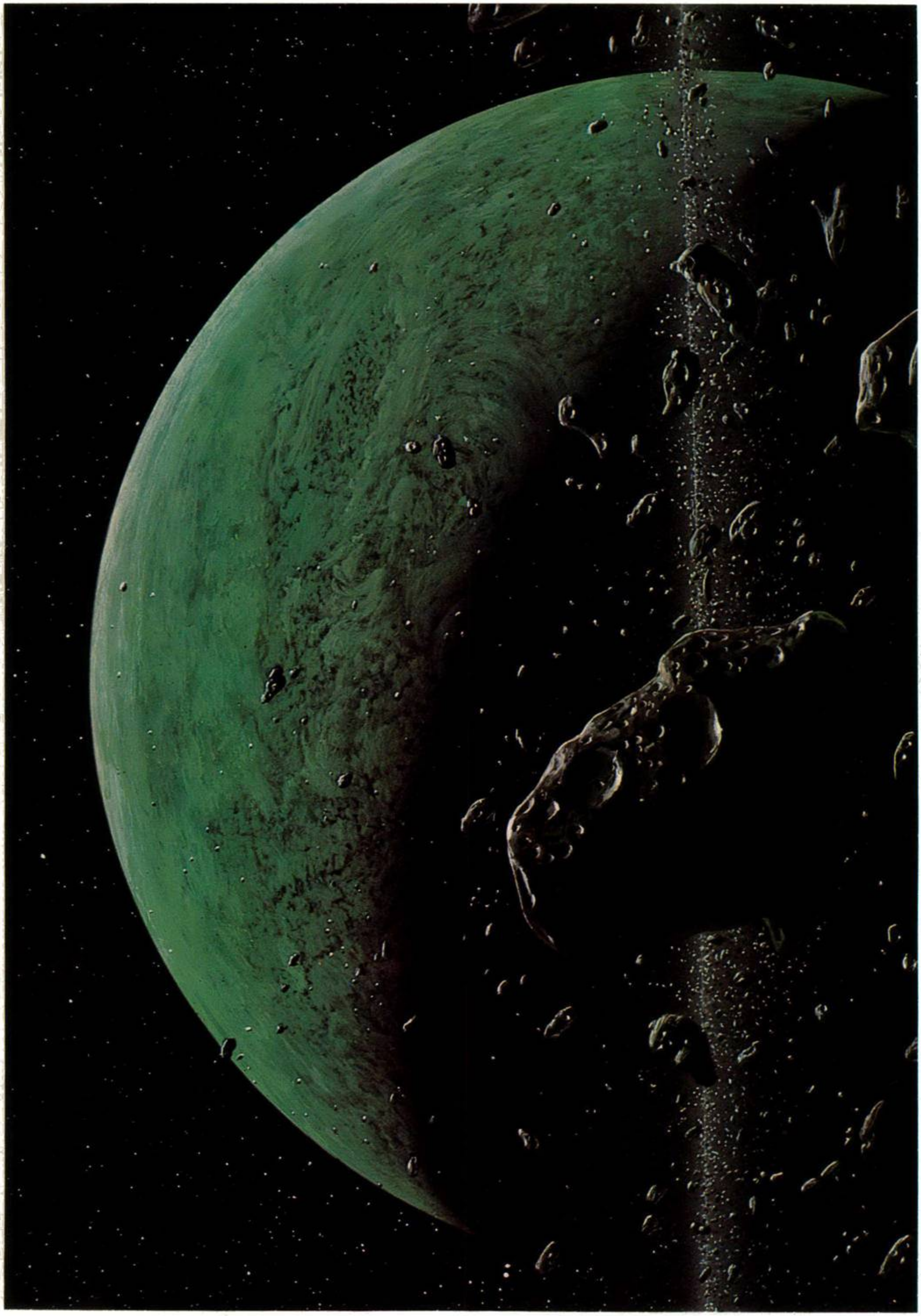
Observations made four days later, on March 17, led Herschel to conclude that his new object was indeed a comet because it had changed position relative to the fixed stars. On the night of April 6, Herschel had steady seeing because the new object appeared to have a perfectly sharp disk, without an accompanying head or tail. This observation should have made Herschel suspect he had erred in the identification of the object. Nevertheless, he presented a paper about his discovery before the Royal Society of England on April 26, entitled "Account of A Comet".

Because Herschel's telescope was only a portable instrument that he dragged outside each evening, he was pleased to have positional measurements made on his new comet by Rev. Dr. Nevil Maskelyne, the fifth Astronomer Royal, who had a permanently mounted telescope. Maskelyne noted from his first view that the new body was as likely to be a planet moving in a circular orbit as a comet moving in an eccentric ellipse because he had not seen evidence of a coma or a tail. It was J. Lexell, J. De Lalande, and other European astronomers who proved beyond all doubt that Herschel's disk shaped object was indeed a planet by noting its slow motion in declination along the ecliptic and by fitting a near circular orbit to its observed motion in the sky. Once a fair orbit had been determined, Johann E. Bode (famed for "Bode's law") made a search of the zodiacal region on contemporary star charts and found that Tobias Mayer had seen and catalogued Herschel's new planet as a star in 1756. Had Mayer observed this star on successive nights and noted its motion, he might have made the discovery 25 years earlier.

The importance of Herschel's serendipitous discovery — the first discovery of a planet in addition to the classic set (Mercury, Venus, Mars, Jupiter and Saturn) — suddenly became apparent outside of the astronomical world, and in July 1782, he was appointed court astronomer to King George III of England. Soon after, he named his new planet "Georgium Sidus", after his royal patron. Since George's star was a misnomer, it became the "Georgian planet" in standard British usage. This was still not acceptable to the astronomical community because it did not follow the mythological nomenclature that had been accepted for the solar system family. Bode suggested the name Uranus, god of sky and husband of Earth, who was also the father of Saturn and grandfather of Jupiter. Although Bode's proposal followed the mythological tradition, the name Uranus was not in common usage for six decades.

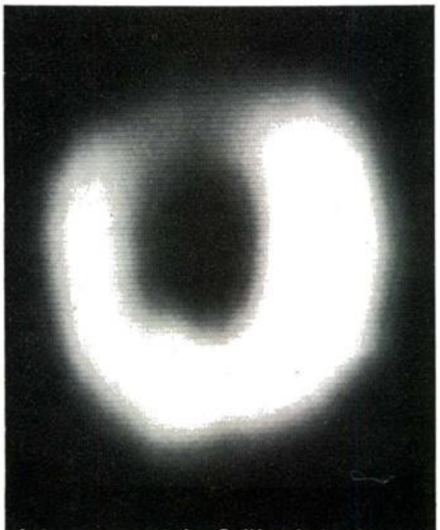
Herschel was naturally interested in learning all he could about the physical conditions of his new planet. If Uranus were like its neighbors,

This rendering of the view inside the rings of Uranus has turned out to be especially accurate in light of the most recent evidence obtained by Caltech astronomers with the Hale Observatories' 200 inch telescope (see the photograph on page 44). The rings seem to be composed of very dark, rocky material as seen here, with none of the glistening ices which characterize (and significantly brighten) the larger ring system of Saturn. Artwork by David Egge.



Jupiter and Saturn, it should appear banded and be attended by many satellites. He saw that Uranus shone with a blue-green light, and with a micrometer of his own invention, he found the diameter to be large — slightly less than that of Saturn. He also suspected a slight polar flattening. He attributed his failure to detect satellites and features on the disk to the planet's great distance and the insufficient light grasp of his telescope.

Early in 1787, Herschel modified his 240 inch focal length telescope to give brighter images by tilting the main mirror and eliminating the secondary flat mirror. This optical arrangement allowed a view directly down at the primary mirror with his eyepiece from the side of the tube. With this superior front view method of observation, he soon discovered two satellites revolving around Uranus in an up and down manner, or approximately perpendicular to the planet's orbital motion. If the satellites' orbital planes were coincident with the planet's equatorial plane, it meant that the tilt of the polar axis of Uranus was greater than all other planets and nearly in the plane of its orbit.

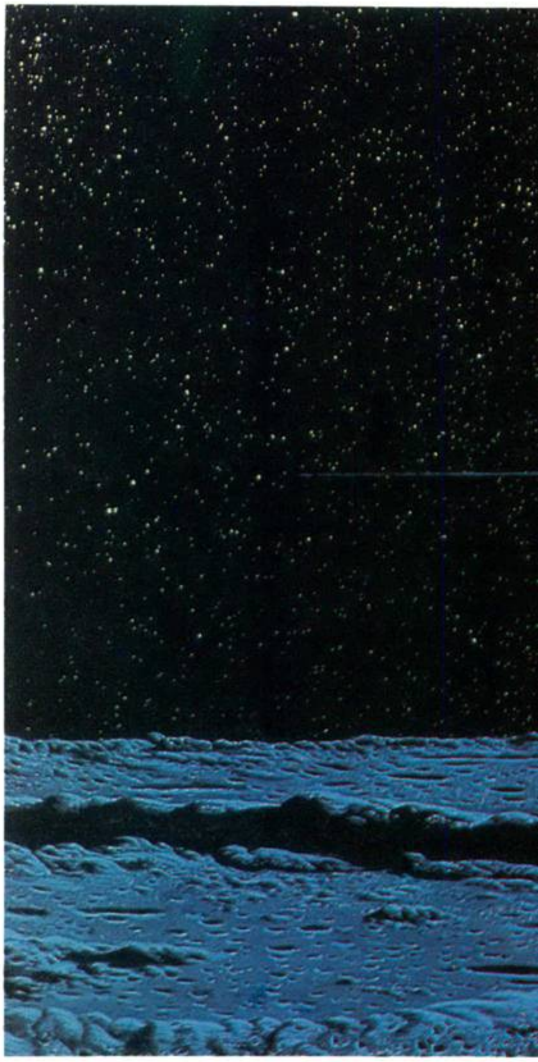


Astronomers at the California Institute of Technology recently obtained the first direct picture of the rings of Uranus. This historic photograph was made with the 200 inch telescope at Mt. Palomar, and shows only the rings, not the planet itself. Uranus was scanned at two infrared wavelengths: one at which the planet appeared brighter than the rings, and one at which it appeared darker. By subtracting one scan from the other, the planet itself was effectively made to "disappear" altogether, leaving the image of the rings. This picture confirms that the rings are, indeed, full rings of material, and that there is a precession of one of the rings about the planet rather like the motion of a hula hoop! It was also found that, unlike the rings of Saturn, Uranus' rings are not icy but probably stony in composition. The rings are actually extremely narrow; the width of the single wide band shown above corresponds to the brightness of the reflected sunlight. In this photo, north is at the top. Caltech photograph.

While studying the motions of these satellites during February and March 1787, Herschel noted a definite polar flattening and possibly two rings at right angles to each other — but gave little credence to the rings. Then a year later, he definitely noted a singular ring that made Uranus appear to bulge at the equator. The ring was blunt, slightly shorter than the outer ring A of Saturn, and seemed to cross in front of the disk; the two areas were reddish in color. Once again, Herschel was cautious and thought the ring might be an optical illusion caused by his metal mirror. He therefore rotated the mirror 90 degrees and found the ring to be in the exact same position as before. It was observed equally well with telescopic powers of 470 and 590, and was steadily seen when the satellites were best in focus. Although Herschel saw or suspected the Uranian ring many times between 1787 and 1893, he was never fully convinced of its reality.

Because the orientation of Uranus' rotation axis is 90 degrees, we see the orbital plane of its satellites, which is presumably coincident with the plane of Herschel's suspected ring, twice edge-on and twice fully open during one revolution or Uranian year. The Uranian ring cannot be resolved edge-on with Earth telescopes if it has a thickness similar to the rings of Saturn. Likewise, it would be most difficult to detect fully open if its density is low. The ring would more likely be visible when inclined to view somewhere between 45 degrees and just before edge-on, when the observer is looking through more ring particles. Of course, its visibility is dependent upon several factors such as the physical nature of the particles, the width and density of the ring, the position of the sun, etc. Herschel detected the ring when it was inclined about 49 to 27 degrees with telescopes that ranged in size from 6.2 to 18.5 inches. His telescopes were of long focal lengths using high powers, which minimized the optical defect known as astigmatism that could have caused a linear flare on a bright object. But even so, Uranus is not a bright object.

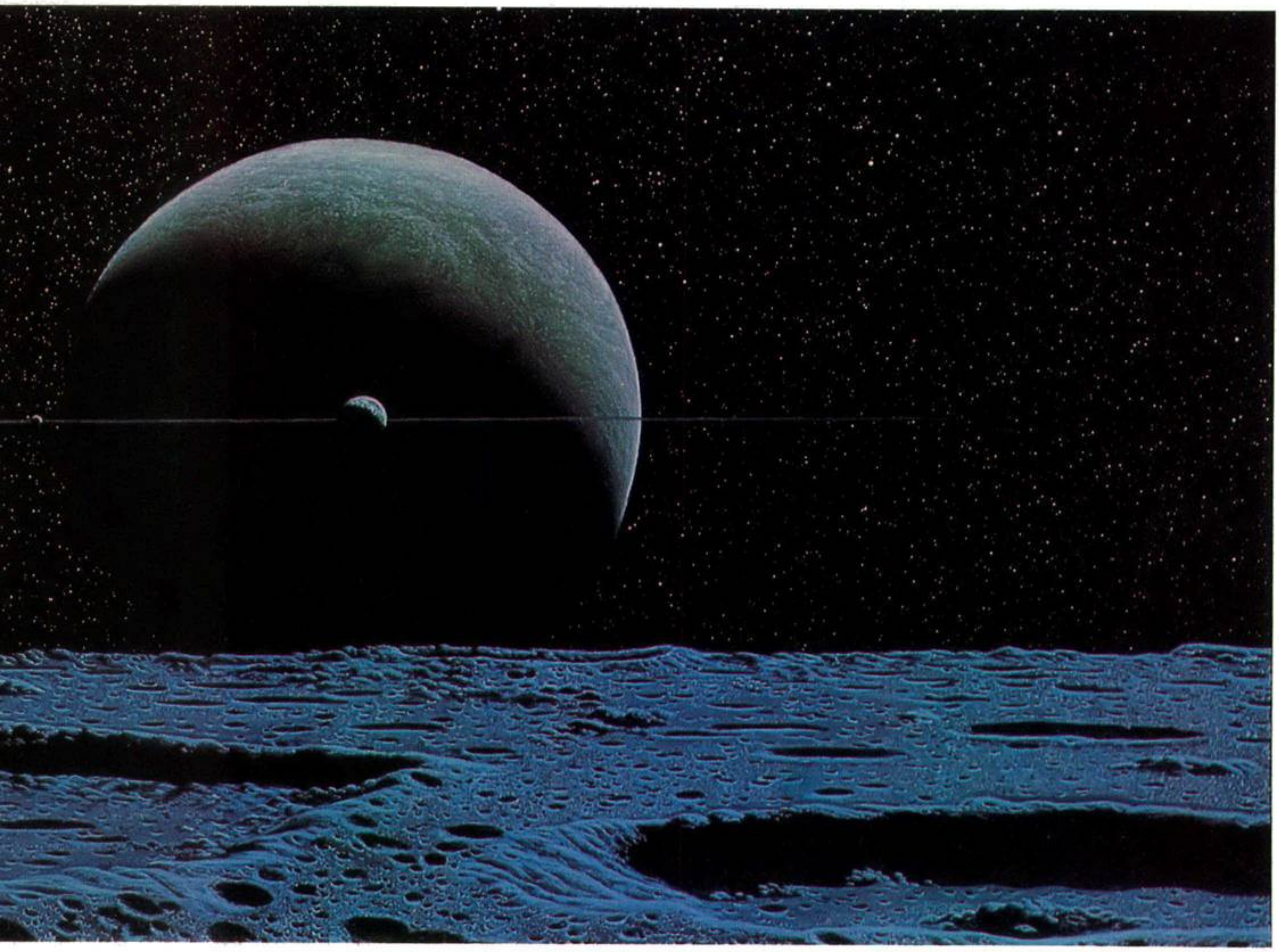
Most astronomers had forgotten about Herschel's ring until a rare event occurred on March 10, 1977, when Uranus occulted a ninth magnitude star in Libra. Scientists from several major observatories planned to *photoelectrically* record the star as it disappeared behind the planet and reappeared again. The occultation was visible only from limited regions on Earth. At several locations, photoelectric observations recorded a series of fluctuations in the star's light both before and after the actual occultation by the disk of Uranus (see "Uranus Has Rings", Astro-News, May 1977).



The dim, narrow rings of Uranus are seen edge-on in this view from the surface of Umbriel. Ariel (right) and tiny Miranda, the two known closer satellites of Uranus, are also visible. The crescents of Uranus, Miranda and Ariel appear tilted against the rings because the axis of Uranus is highly inclined to the plane of its orbit. Artwork by David Egge.

The first interpretation of these extraordinary photoelectric data was that solid bodies, such as moonlets, were interrupting the star's light. Later, comparison of all the data showed that the dips in the signals were symmetric about the planet, which changed the interpretation to that of a system of five rings. More recently, other observations have shown four additional rings circling the planet, for a total of nine.

The nine confirmed rings lie on a plane with Uranus' equator, with the innermost ring at a distance of 25,200



miles (42,000km) and the outermost at 30,500 miles (51,000km) from the planet. The most interesting (and largest) ring is Epsilon, which seems to have a highly complex structure. Epsilon is also the widest; all the others are quite narrow. Thus, Saturn no longer holds its unique place as the only ringed planet in our solar system.

Back in the 1870s, S. Newcomb, observing with the 26 inch refractor at the U. S. Naval Observatory, stated that the four visual satellites disappeared in the glare of Uranus at a distance of 10 seconds of arc from the disk. However, G.P. Kuiper, using the high quality 82 inch reflector at McDonald Observatory, discovered the fifth satellite, Miranda, at less than 10 seconds from the planet on a long exposure photograph taken Feb. 16, 1948. No mention of a ring appeared in any of Kuiper's numerous reports.

Wishing to investigate Herschel's classical observations with superior instrumentation, Charles Capen (the author) observed Uranus for physical features, color and the Herschel ring in 1968 and 1969 with the same McDonald 82 inch reflector. The equatorial plane was opening and ideally inclined between 9 and 13.5 degrees. Only amorphous light and dark patches were seen on the disk. Photographic colorimetry indicated that Uranus was more blue than yellow-green. No ring was detected visually, and long exposure photographs were inconclusive because the enlarged images would probably have hidden any faint and nearby rings.

Why haven't modern visual observations made with large and superior telescopes detected the Uranian rings? Perhaps the rings are the result of a dynamical breakup of a large satellite in retrograde orbit which spiraled in too close to the giant planet. The ring system may be a recent and short-lived formation that is rapidly dissipating and thinning out due to gravitational forces. But this is doubtful.

The question still remains, is the newly discovered Uranian ring system the same as that observed by Herschel? According to the drawings in his observing log, the Herschel ring is to the proper scale and in the equatorial plane. Since Uranus and Neptune share similar physical characteristics with their neighboring planet Saturn, it was common for classical astronomers of the 18th and 19th centuries to suppose that these two newly discovered planets should also have a ring system. In fact, less than a month after the discovery of Neptune (in September 1846), William Lassell, an experienced observer, announced to the press that he had discovered a ring and satellite revolving about the new planet. Lassell used a superior 24 inch reflecting telescope with 316 and 567 powers. The ring was confirmed by other qualified observers using large refracting scopes, but seemed to vanish in later years and has never been observed since. Could these observations of the rings be just wishful or suggestive thinking on behalf of these reputable astronomers? With the exception of the highly processed image on page 44 (obtained with the Mt. Palomar 200 inch telescope), all modern attempts to directly observe the rings of Uranus have failed, and no rings have yet been detected around Neptune. But perhaps future observations utilizing new techniques, or a planetary probe, may show rings around Neptune as well!

Hunt A Cluster!

by

Robert Burnham

Anyone who's ever looked more than casually at the sky is familiar with at least two open clusters, the Pleiades and Hyades. If you've observed a little more, you probably also know of a few others — maybe Praesepe or the Double Cluster. But if that's the extent of your acquaintance with open clusters, you're missing out on a lot! There are a great many interesting and attractive clusters besides these, just waiting to be found by you! Why not set up tonight and start browsing through the galaxy's collection of pretty star groups?

Open, or galactic (as they're sometimes called), clusters result when a dust and hydrogen gas cloud condenses into stars. The process happens continually, so we're seeing clusters of all possible ages — a fact that has helped astronomers piece together the tangled story of how stars evolve. Generally, young clusters are more tightly grouped, wreathed in residual dust or gas, and contain hot, very bright, massive stars. As the cluster ages, the gas disperses, the stars drift apart, and the brightest, most massive stars evolve into red giants. Eventually, the cluster becomes so aged and dispersed that it is indistinguishable from the common stars of the Milky Way. Clusters serve as the galaxy's star factories, enriching the disk population with new stars.

And they're *everywhere*! No matter where you look in the Milky Way, you can't help finding one or two after a short search. Some are large and distinctive; others fade imperceptibly into the background. Many have been catalogued and described, but in your sweeps, you'll see little knots of stars which probably are clusters but are unknown to any catalog. (If you want, make up your own list!)

To help your search, we've made a roster of the brighter open clusters from Cassiopeia down through Auriga and Gemini to Canis Major. This represents about half the Milky Way that's visible from 40 degrees north latitude, and will give you a challenging observational program for the winter! How many of them will *you* be able to pick out?

While a few of the clusters are naked eye and many are visible through binoculars, you'll need a telescope to find all on the list. If the scope is equatorially mounted with setting circles, your sweeps will progress a lot more smoothly. But if all you have are binoculars, don't despair! You'll still be able to hunt out many of them. In addition, your wider field of view puts you at an advantage in revealing rich expanses of stars. You'll need a good star atlas; **Norton's** is okay, but the **Atlas of the Heavens** is better because it shows the position of all clusters on the list — a real help when you're scanning for a dim little group.

The list itself is on page 51, but since a few items deserve special treatment, we've highlighted them.

The Pleiades

This renowned cluster is one of the two naked eye resolvable ones in the sky (the Hyades is the other), and is known by many people even if they have no special interest in the sky. It's a young cluster: Astronomers figure it formed about 20 million years ago. Long exposure photographs reveal it's still embedded in a dust cloud which can be glimpsed in a telescope, but use at least four inches aperture and wait for a very dark black night. Even then, you'll need to look slightly to one side of it — an old observing trick called averted vision.

Test your eyesight by trying to see how many Pleiads you can spot with the naked eye! Most people see six (which has long prompted the question of what happened to the seventh Pleiad of the legend). Some can make out eight or nine; one author saw 12 when he was a child, and the record seems to be 18! In a way, it's not a true test because you know that there are several stars hovering just around the verge of detectability, making it easier to tell yourself you can see them.

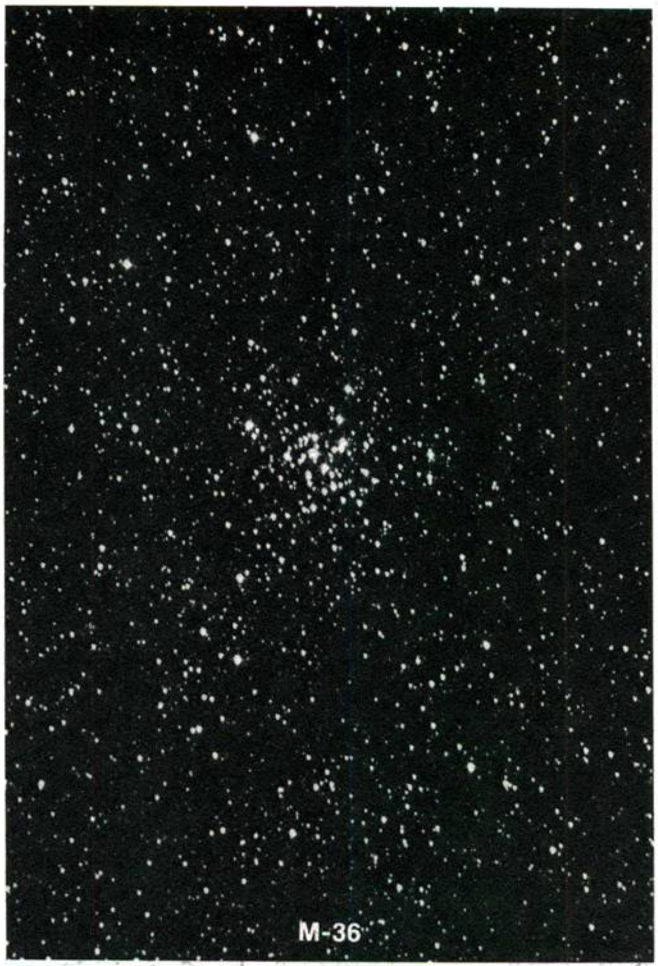
The sparkling Pleiades are one of the grandest sights of the winter sky! M-41 lies very close to Sirius, the brightest star in the heavens. M-103 resides in Cassiopeia, nestled in the Milky Way. The Double Cluster marks the sword handle of mythical Perseus. Photographs by (left to right, top to bottom) Robert Burnham, Paul Avellar, Lester Yuill, Robert Burnham.

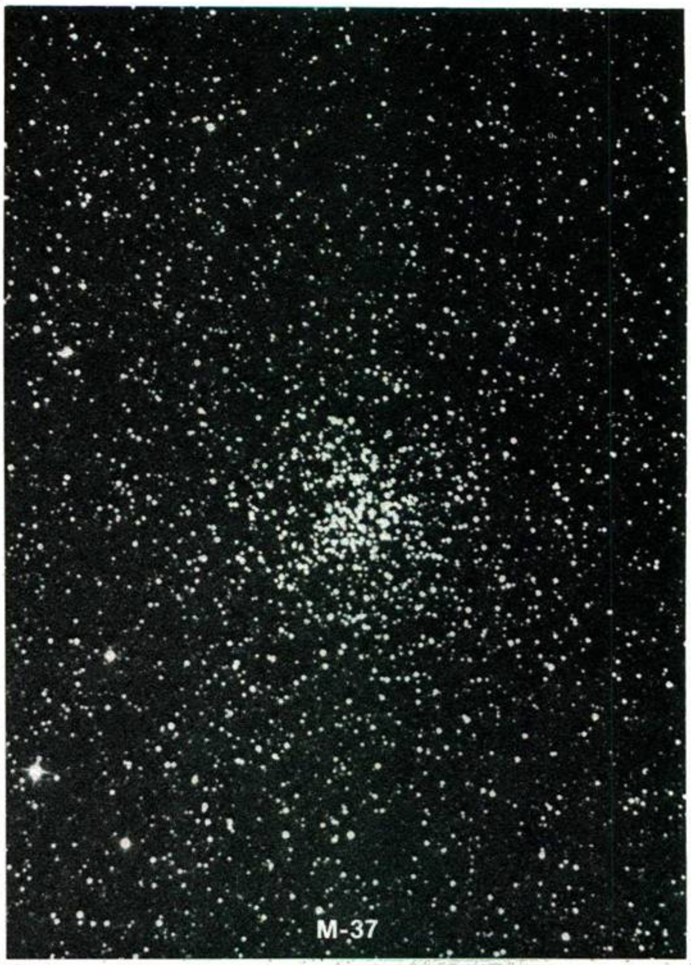
Pleiades

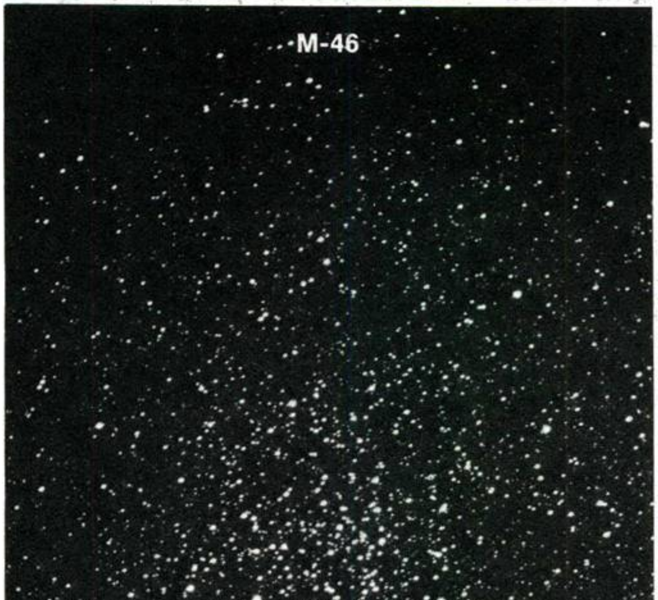
M-41

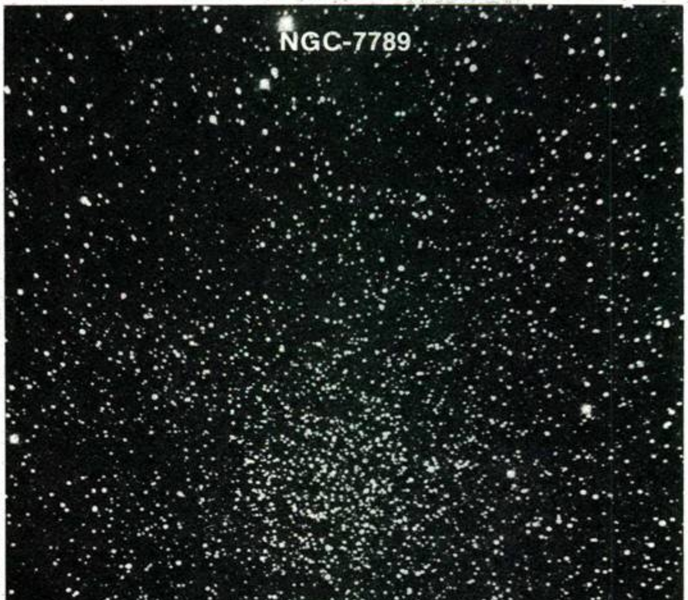
M-103

Double Cluster


M-36


M-37


M-46


NGC-7789

Left: The large dispersed open cluster M-44 (the Beehive) spreads in the center of Cancer. The view you'll get of the cluster this winter will be the more dramatic because of Jupiter's presence in the neighborhood. Observe this cluster at its best in binoculars or an RFT. Photograph by Rick Dilsizian.

Books and Charts for Cluster Hunting

Norton's Star Altas — has charts on scale of one degree equals 3.3mm. Lower magnitude limit is six.

Atlas of the Heavens by Antonin Becvar — charts are scaled one degree equals 7.8mm; lower magnitude limit 7.75.

Celestial Objects for Common Telescopes by T. W. Webb — lists all sorts of objects, including clusters, for northern hemisphere observers. In two volumes: I Solar System, II Stellar.

Burnham's Celestial Handbook by Robert Burnham Jr. — updates Webb, and concentrates entirely on nonsolar system objects. Very good general reference book, in three volumes. (By the way, its author is no relation to the author of this article!)

Left: M-36 and M-37 are two clusters in Auriga. Note the triangular shape of M-37. M-46 lies to the south in Puppis, and is famous for the small planetary nebula within it. NGC-7789 is a small dim condensation of stars in Cassiopeia. Photographs by (left to right, top to bottom) Walter E. Hamler, Walter E. Hamler, Bill Iburg, Yerkes Observatory.

Your best view of the group will be in binoculars or a richest field telescope like an Astroscan or Star-Trap. The cluster spreads out over a degree in the sky, so with high power, the glory is substantially diminished. Fifteen power will fill the eyepiece with a riot of sparkling diamonds! You'll wonder and marvel at the fortune that placed such a grand sight so close to us!

The total number of stars in the group is around 400, spread out in a sphere 50 light-years in diameter. Almost all the stars you see in and around the cluster are physically members of it. About the middle of the last century, the astronomer Maedler thought that Alcyone, the brightest star in the group, was the "central sun" of the galaxy. He came upon this strange notion when it was learned that the Pleiades all have little or no motion relative to each other. The idea didn't last long, but studies of the tiny individual motions of each star have proved a good test for cluster membership in this and in other clusters.

The Pleiades is one of those groups you'll seem to come back to again and again, each time reveling in the glorious sights!

M-35

Look just to the north of the feet of Gemini some clear dark night and you'll spy a faint patch of light. This is M-35, a rich open cluster lying at a distance of some 2,800 light-years. Binoculars will start to resolve the cluster members, but a telescope is needed to finish the job. Because the cluster has an apparent extent of 30 minutes of arc, you can use medium-high powers without losing the edges of the group.

You'll see a smoothly distributed field of stars that seems to be arranged in rays and arcs. Your eyes will do this to you in a number of cases; it seems as if they dislike a random spread and want to find patterns! Most of the stars are of eighth to ninth magnitude and fainter. One observer compared the sight to that of a skyrocket burst — long curved arcs.

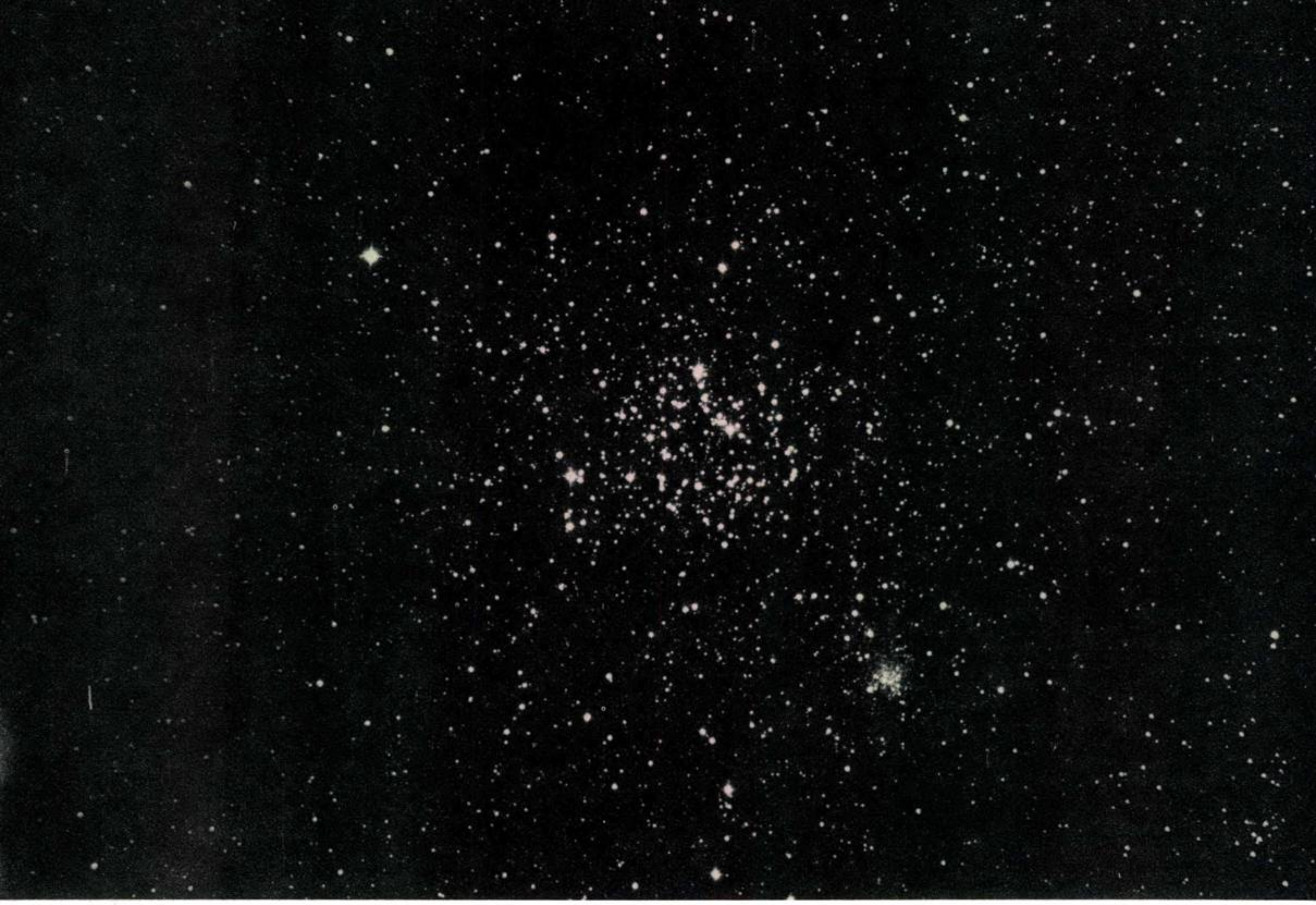
M-35 is a young cluster — even more so than the Pleiades, which makes one compare the two. M-35 is a rich cluster, but appears to have little residual gas or dust. It's still well-concentrated and has many, many stars below the level of eyepiece visibility. As a star group ages, often the members slowly drift apart, sometimes due to their own intrinsic velocities, and sometimes because of the gravitational pull of other stars and material in the galactic plane.(The Hyades is just such an old, dispersed cluster.)

Just to the southwest of M-35, 15 minutes of arc from the cluster center, your telescope will show a small fuzzy spot. This is NGC-2158, another open cluster but vastly more distant than M-35. Its brightest stars are about 11th magnitude and it resembles a fat wedge. You'll need a large aperture (eight inches or more) at high magnification to resolve it into stars.

M-44

Also known as Praesepe (the manger) or the Beehive cluster, M-44 lies in the center of the zodiacal constellation Cancer. It's another of the widespread clusters, best seen in binoculars or an RFT. When you look at it, the open sparse nature of it is readily apparent, which ties in with its great age (400+ million years). You'll see about 75 stars in a central region of about 11 light-years diameter, but there are some 150 more scattered in the outlying regions.

Praesepe was one of the first "nebulosities" to be resolved into stars (by Galileo with his new telescope in



M-35 and its distant optical companion NGC-2158 were captured on film. One of the finest open clusters in the heavens, M-35 offers magnificent fields to sweep in, while NGC-2158 challenges your observing skills a bit. Photograph by Robert Provin.

1610). It hovers right on the edge of naked eye resolvability, and there have been persistent reports of people actually seeing it as stellar. The claims may well be true since you'll need only the slightest optical aid to resolve it. As an added attraction this year, Jupiter is in the vicinity of the cluster all winter, passing south of it during the first week of January. Binoculars or an RFT will show the sights very well!

M-41

'Way down to the south, four degrees due south of Sirius, lies a beautiful naked eye cluster, M-41. It is loosely condensed, but rich in numbers of stars. Binoculars will resolve the outer parts, but to see into the heart of it, you'll need a telescope. About the same apparent size as the moon, you'll see about 20 bright stars and 75 dimmer ones. As in the case of M-35, it sorts itself into various rays and arcs. Near the center is a ruddy orange star suspected to be slightly variable.

M-41 is older than the Pleiades but still young in cosmic terms — about 100 million years old. It was known to the Greeks as one of the hazy stars in the sky. Its outline is roughly circular and its angular diameter corresponds to a size of 20 light-years at the distance of the cluster.

h and χ Persei (NGC-869, 864)

The famous Double Cluster is a beautiful group surprisingly not included in Messier's list. It's clearly visible to the naked eye as an oval hazy spot one degree in diameter, halfway between Cassiopeia and the main part of Perseus. Binoculars show you the two knots of the clusters very well, surrounded by lots of field stars. Look for a long arc of stars pointing back up the Milky Way toward Cassiopeia. Fifteen power will just contain the two clusters in the field of view; 30x to 40x will give the most dramatic view, letting you probe into the depths of the clusters. Several stars will show colors, mostly reddish. h and χ are very young clusters, having only a few members evolved away from their initial states.

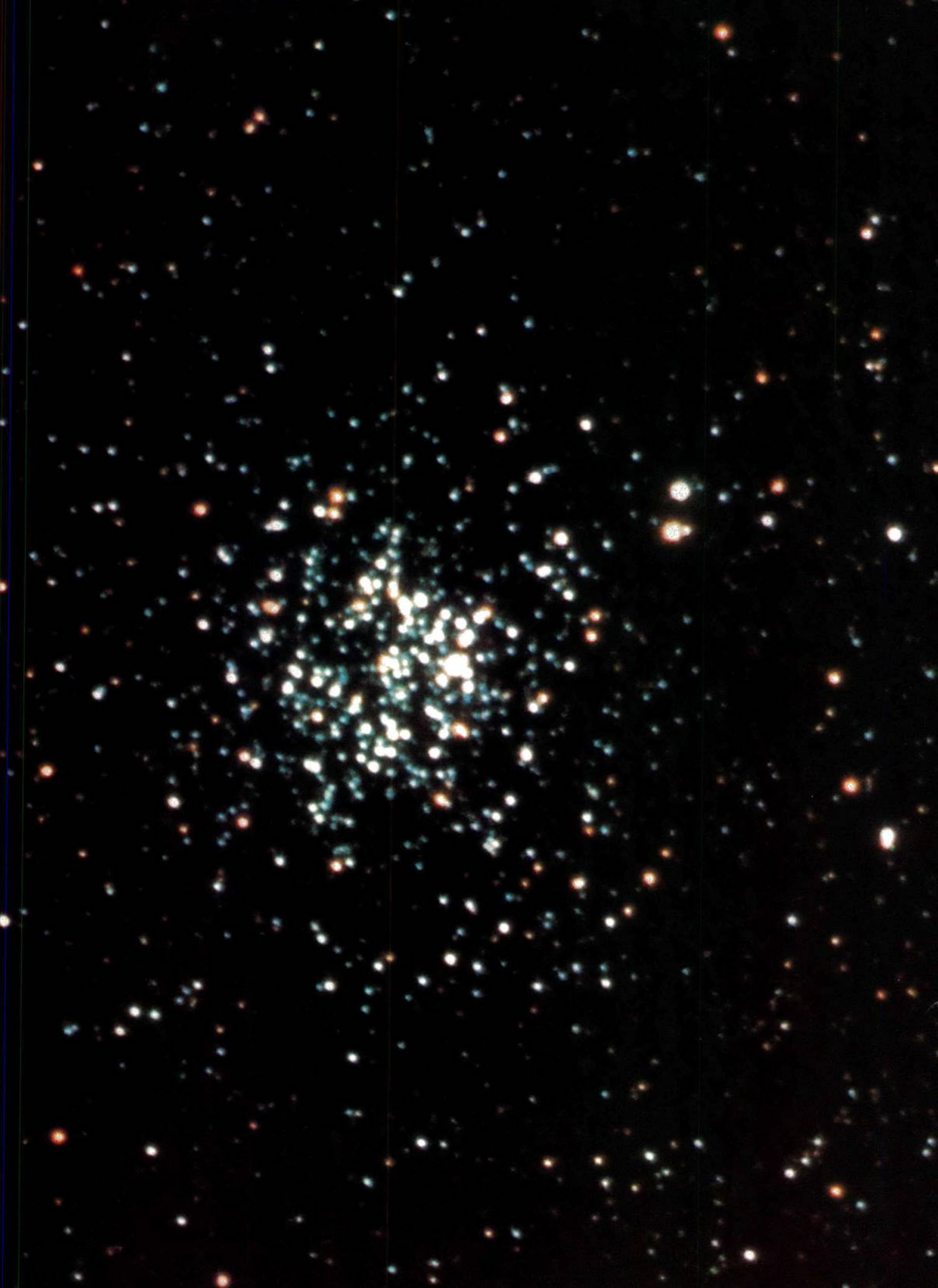
Look carefully and you'll observe that the western cluster, NGC-869, has, by a slight margin, a few more bright stars than the other one. Both clusters are about 7,300 light-years away, which means their apparent size translates to 75 light-years diameter in space. If each cluster has about 600 stars, the space density is such that on the average, stars lie only 4-1/2 light-years apart. While this is about the average distance between stars in the sun's neighborhood (most of which are dim red dwarfs), remember we're talking about having stars as big and bright as Rigel at the same close distances!

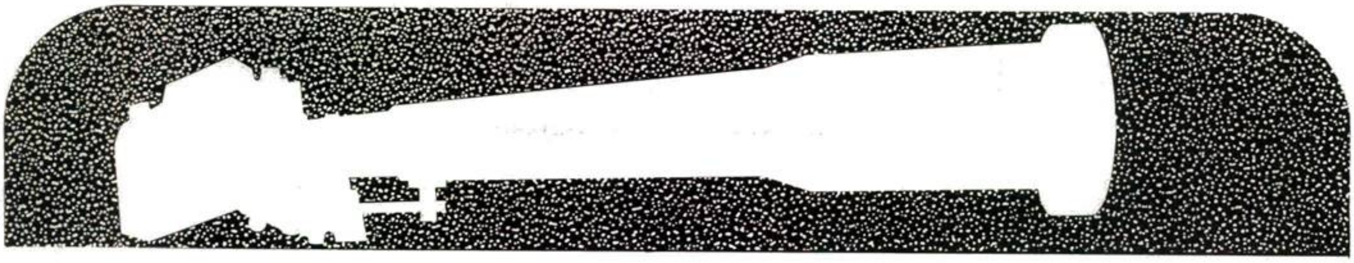
In the table that follows you'll find each open cluster listed by constellation. All of them are visible to the eye in a telescope, but some, being more of a challenge, need large apertures to pick them up in detail. If you're just starting to observe, try the easier ones (marked by **bold type**) and then go after those more difficult when you've gained some experience. Soon you'll develop an ability to pick out the cluster from the background; often sweeping slowly in right ascension past the object will help you pull it out of the field stars. Once you've found it, you can put on as much power as the object warrants, moving in closer on it!

For the benefit of astrophotographers, the table lists the size — in millimeters — of the clusters on film as photographed with a one meter focal length lens. Multiply the focal length of your camera system in meters by the value given to find the size of the cluster on your film. (See this month's Photography in Astronomy for details.) Good luck and good hunting!

Constellation	R. A. (1950)	Dec.	d	m	mm	Remarks
Cassiopeia						
M-52	$23^h22.0^m$	+61°20′	9	7	2.6	= NGC-7654; rich and compressed; has a red star near SW edge
7789	$23^h55.0^m$	+56°26′	23	9.6	6.5	somewhat resembles a globular cluster; faint
457	$01^h16.0^m$	+58°04′	8	7.5	2.2	distinct group; stands out well from background; nearby is NGC-436, 35′ to the NW
559	$01^h26.1^m$	+63°02′	5	7.3	1.5	small group between 2 brighter stars
M-103	$01^h29.9^m$	+60°27′	5	6.2	1.3	= NGC-581; moderately rich; easily seen against background; looks triangular
663	$01^h43.0^m$	+61°01′	8	7.1	2.4	bright little group; near NGC-654 and NGC-659 which lie to the NW and SW respectively; each is a little knot of stars
1027	$02^h38.8^m$	+61°20′	5	7.5	1.5	well-condensed though small; one bright star
IC-1848	$02^h47.3^m$	+60°14′	13	7.6	3.7	hard to tell cluster from field; fainter stars are cluster members most likely
Andromeda						
752	$01^h54.7^m$	+37°25′	35	7.0	9.8	loose, but plentiful; use low powers and sweep for it
Camelopardalis						
1502	$04^h03.0^m$	+62°11′	5	5.3	1.5	tiny brilliant knot; use high powers when found
Perseus						
869	$02^h15.5^m$	+56°55′	25	4.4	7.1	= h Persei
884	$02^h18.9^m$	+56°53′	25	4.7	7.1	= χ Persei
1245	$03^h11.2^m$	+47°03′	12	6.9	3.7	well-condensed; has brighter stars on 3 sides
1342	$03^h28.4^m$	+37°09′	11	7.1	3.3	loose group; relatively bright
1513	$04^h06.2^m$	+49°23′	9	8.8	2.6	not very distinct; small and dim
1528	$04^h11.4^m$	+51°07′	19	6.2	5.4	moderately compacted; has lines of stars
M-34	$06^h05.8^m$	+24°21′	30	5.3	8.7	= NGC-1039; large, loose; has a few arcs of stars; stands out in region
Auriga						
1664	$04^h47.4^m$	+43°37′	11	7.5	3.3	has concentration but somewhat lost in field; sweep past to see it
1893	$05^h22.4^m$	+33°21′	9	8.0	2.6	small and embedded in gas (photos show)
M-38	$05^h25.3^m$	+35°48′	15	7.4	4.3	= NGC-1912 These 3 are all conspicuous and relatively bright; all reasonably condensed; near M-38 is NGC-1907, a tiny cluster of 40 stars about 10th magnitude.
M-36	$05^h32.9^m$	+34°07′	9	6.3	2.6	= NGC-1960
M-37	$05^h49.0^m$	+32°33′	15	6.2	4.3	= NGC-2099
2281	$06^h45.8^m$	+41°07′	13	6.7	3.7	in a rich field; sweep past to locate
Taurus						
M-45	$03^h43.9^m$	+23°58′	100	1.4	28.6	= Pleiades; terrific!
Hyades	$04^h16.7^m$	+15°31′	330	0.8	94.3	use binoculars!
1647	$04^h43.2^m$	+18°59′	30	6.3	8.7	moderately bright; large and loosely condensed
1746	$05^h00.6^m$	+23°44′	34	6.0	9.8	wide spread; not very concentrated
1807	$05^h07.8^m$	+16°28′	8	7.9	2.2	this merges into one group due east of the Hyades and is very loosely gathered
Gemini						
IC-2157	$06^h01.8^m$	+24°02′	3	8.5	0.9	tiny knot of stars; sweep past to catch
M-35	$06^h05.7^m$	+24°20′	35	5.3	9.3	bright and gorgeous!
2266	$06^h40.5^m$	+27°02′	4	9.8	1.2	small triangle of 10th magnitude stars
2355	$07^h14.7^m$	+13°52′	7	12.2	2.1	very faint and small; use big aperture
2420	$07^h35.4^m$	+21°41′	6	10.2	1.6	you'll need a close look to distinguish from a star!
Cancer						
M-44	$08^h37.5^m$	+19°52′	90	3.7	26.1	use a wide field eyepiece or binoculars
M-67	$08^h48.3^m$	+12°00′	12	8.3	3.5	poorly defined in a rich field; elongated in a NE-SW direction
Monoceros						
2215	$06^h18.4^m$	-07°16′	6	8.6	1.9	wedge shaped; brightest in SE
2244	$06^h29.7^m$	+04°54′	32	6.2	9.3	clusters at heart of Rosette nebula
2264	$06^h38.4^m$	+09°56′	30	4.7	8.7	bright stars in a wisp of gas; looks like "?"
2301	$06^h42.2^m$	+00°31′	12	5.8	3.5	elongated in a N-S direction
2324	$07^h00.4^m$	+01°08′	7	8.8	2.1	sweep past to catch the brightening at the cluster's location
M-50	$07^h00.5^m$	-08°16′	13	6.9	3.7	= NGC-2323; look for many arcs of stars
2335	$07^h04.2^m$	-10°00′	10	9.1	2.8	small knot; well-concentrated; look for others in area
2353	$07^h12.3^m$	-10°12′	16	5.3	4.6	bright and crowded!
2506	$07^h57.8^m$	-10°29′	8	11.5	2.3	dim but condensed; looks like 2 shells of stars
Orion						
2169	$06^h05.7^m$	+13°58′	4	6.4	1.2	small but moderately bright; not very plentiful, so look carefully
Canis Major						
2204	$06^h13.5^m$	-18°35′	10	9.1	3.0	relatively faint and loose; sweep past to get
M-41	$06^h44.9^m$	-20°42′	30	5	8.7	= NGC-2287; bright!
2360	$07^h15.4^m$	-15°33′	10	9.5	2.8	slightly oval; well-condensed little group
2362	$07^h16.6^m$	-24°52′	5	10.5	1.4	cluster surrounds 4th magnitude Tau Canis Majoris

The first column has the object's NGC number (or Messier number if prefixed M-). The next two columns give epoch 1950 coordinates. Next, the diameter in minutes of arc is given, followed by the integrated magnitude of the cluster, and its size on film using a 1,000mm focal length lens. (Multiply this figure by the fraction your lens length is of 1,000mm, and you'll predetermine the size of the cluster on your film. For example, with a 500mm lens, your size on film of the cluster will be 1/2 the value shown; if you were using a 2,000mm lens, the size on film would be twice that given here.)





Photographing Star Clusters

by

Richard Berry

Star clusters present a different type of photographic challenge than nebulae and galaxies do. Both nebular and galaxian images are extended images — images that cover a substantial piece of sky. Such images become brighter with short focal ratio telescopes and dimmer with large focal ratio instruments. But star clusters are different: They are collections of tiny point images — images which stay the same brightness regardless of the mirror's focal ratio. For star clusters, then, the focal ratio of your photographic equipment does not matter very much. The telescope aperture and its focal length still do, however; the aperture determines how quickly you can record faint stars in the cluster, while the focal length of the telescope determines the image scale.

What kind of telescope makes a good photographic instrument for star clusters? Any reflector will do a creditable job — even those with focal ratios slower than f/8. Such slow systems require long exposures to make good nebula or galaxy pictures. Of course, the bigger the mirror the brighter the star images: Six inches aperture (or more) is desirable, but even a four inch telescope will do a good job. Refractors, though usually not taken too seriously for deep sky astrophotography (f-ratios of f/15 are common), do well on star clusters.

Don't overlook the power of a good 35mm camera and its lenses either. Even the "normal" lens and a slow slide film are capable of recording an amazing number of clusters along the plane of the Milky Way as faint little blobs of light. Telephoto lenses need to be long by terrestrial standards — 400mm and up will break many Messier objects into satisfyingly clustery little balls of stars.

Films? As usual, the best bet is one of Kodak's spectroscopic emulsions — the familiar 103a series. Because clusters tend to be fairly young objects with lots of blue stars, the "O", or blue sensitive emulsion, is probably best, though you'll still do very well with the more versatile "F" emulsion. The fast color films just coming out on the market — particularly Kodak's Ektachrome 400 — promise to be good, especially if exposed on chilly nights or in a cold camera to minimize reciprocity failure. For relatively bright clusters, Tri-X and HP-5 (Ilford's contender for the all-around fast film championship) are good choices, and have the advantage of being inexpensive compared to spectroscopic films.

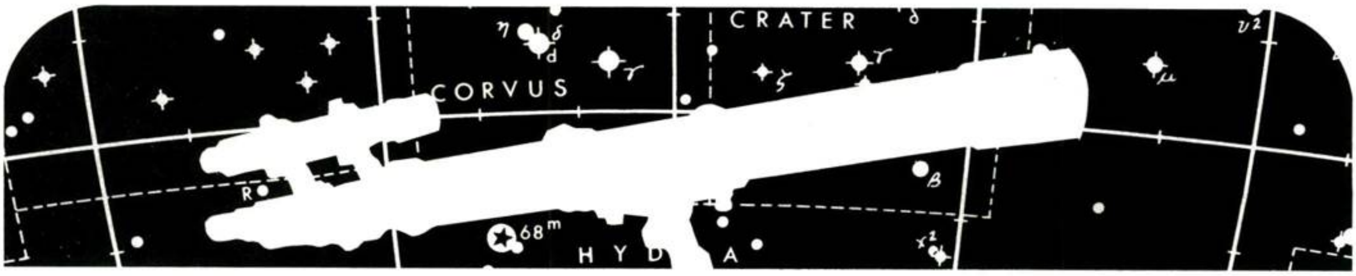
One thing you need not worry about with clusters is lack of subject matter. The sky is full of star clusters — and many are surprisingly bright and easy to photograph. This month's Gazer's Gazette lists many of the brighter and better known clusters, and you can consult the Skalnate-Pleso **Atlas of the Heavens** for more, so there's little danger you'll run out. You can even find clusters yourself by searching pictures taken with a 50mm lens (along the galactic plane lie the best search grounds); then zero in on fuzzy spots you suspect of being a cluster with a telephoto lens or telescope.

Once you've got the cluster centered in the field, and a guide star on the crosshairs, you may suddenly find yourself wondering how long the exposures should be. "Expose as long as you can without getting too much sky fog" is the answer. If your site is good and your focal ratio long, it could run into hours! If the sky is bright with light pollution or the focal ratio is small, you may be limited to a few minutes.

Making prints of star clusters also presents a rather different problem than making prints of nebulae. You may find that high contrast techniques which work so well for nebulae leave clusters looking more like little heaps of dirt specks on the film than glittering clusters of stars. Lower contrast prints preserve more of the tonal scale of the original negatives, and may approach the visual appearance of a cluster far better. To some extent, it's a matter of personal preference — if you like jet black backgrounds, then the high contrast techniques are probably suitable for you.

The pictures here and in Gazer's Gazette should be both an inspiration and challenge to you, whether you're a beginning astrophotographer or an old pro.

Just a glow in a small telescope, and a spangle of stars in a big telescope, M-11 reveals its true colors to the astrophotographer willing to make long exposure photographs. Taken with a five inch f/10 catadioptric, High Speed Ektachrome film (ASA 160) was exposed for 30 minutes in a cold camera. Modern high speed color films should require far shorter exposure times. Photograph by Leo C. Henzl Jr.



A Simple Low Cost Mounting

(That Lets You Sit Down While You Observe)

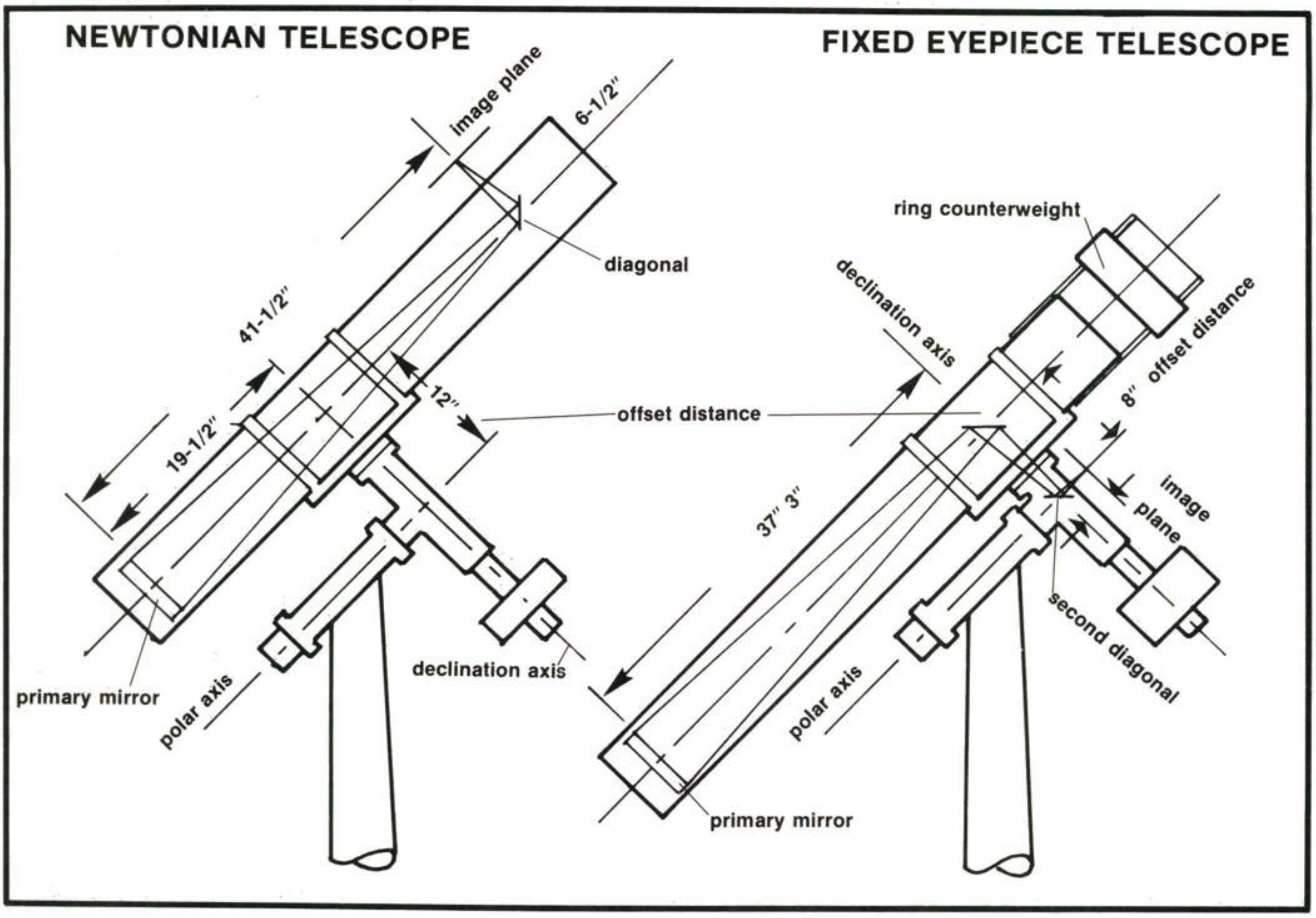
by

Earle Dodds

Newcomers to the hobby of telescope making usually choose the six inch f/8 reflector for their first instrument, and the classical Newtonian light path and conventional German style equatorial mounting. This system has a lot going for it. It probably gives the user the best deal, in terms of image quality and cost, that there is. But it does have one serious disadvantage: The eyepiece is way out near the open end of the tube. As the telescope is directed to different areas of the sky, the eyepiece can get into some of the most awkward and inaccessible positions imaginable. In a well built instrument, the tube can be rotated within the cradle to alleviate the problem somewhat. But even so, when the tube of a large instrument is pointed anywhere in the general direction of the zenith, the observer will probably have to use a stepladder to get to the eyepiece. This is hardly conducive to the most effective observing.

Experienced observers know that being comfortable and relaxed when looking through a telescope is important. But somehow, it's hard to get comfortable or relaxed while standing on tiptoe or perched on a stepladder. Now consider a telescope in which the eyepiece never moves; no matter where it's pointed, the eyepiece stays in one comfortable location.

The mounting is still a German style equatorial, and the light path is still essentially Newtonian. True, there is a second passive reflective surface, but the focal length is not altered by this second deflection of the converging light cone. The declination axis is a



NEWTONIAN TELESCOPE

FIXED EYEPIECE TELESCOPE

hollow tube instead of the solid shaft that is usually used. The customary diagonal mirror is placed at the intersection of the tube axis and the declination axis, and it's oriented so the converging cone of rays is deflected through a hole in the wall of the tube and then along the hollow declination axis. A second diagonal reflecting surface (usually a right angled prism) is placed at the intersection of the two principal axes of the mounting so the still-converging cone of rays is deflected a second time — this time upward along the polar axis and through an opening in the mounting so the image is formed where it can be examined with an eyepiece. Examination of this light path shows that the image position is stationary, regardless of the direction in which the tube is pointing. The observer can sit on a high stool or stand to study the field of view — much as a laboratory scientist examines a specimen with a microscope. No mounting produces a more natural, comfortable observing position.

Building

Now, if you've been persuaded to try a stationary eyepiece type instrument, your next question is, "How do I build it?" A first telescope ought to be stripped down to the bare essentials: no setting circles or clock drive, no slow motions on the two axes, no fancy eyepiece focuser or finder — nothing but the two axes carrying the tube and the optical train. A mounting fabricated out of standard pipe fittings meets these specifications very well. One advantage of a pipe fittings mounting is that it lends itself quite readily to the stationary eyepiece concept. In fact, as far as the configuration of the mounting components is concerned, it makes little difference whether the conventional Newtonian or stationary eyepiece optical path is used.

Some advanced telescope makers, who seem to have forgotten or are ashamed of their earlier days, are inclined to look askance at mountings assembled from pipe fittings, derisively calling them "plumbers' nightmares". But this criticism is not justified. You can do a lot worse, particularly on your first or second instrument, than to use standard pipe fittings as mounting components. They are ubiquitously available in a wide variety of sizes and configurations; they are strong, rigid and relatively inexpensive. The standard pipe tee, for example, is hard to beat as the member for joining together the two principal axes of a mounting, and a close nipple is a natural for the hollow declination axis of a stationary eyepiece mount.

Pipe Mountings

There is considerable range in the way standard pipe fittings can be assembled to make an approximately equatorial mounting, depending upon the availability of some fittings in the sizes used (see the drawing on page 56). For example, if 45 degree street ells are available to you in this size, you might use a regular 45 degree ell with a close nipple between the 4x2 inch bell reducer and the 90 degree street ell which screws into the junction tee. But the arrangement using the 45 degree elbow is advantageous because it puts the geometric center of the tee (which also has to be the center of gravity of the entire mounting, if it is properly balanced) directly over the pier.

Pipe fittings mountings — as they've usually been made — have a disadvantage: Standard fittings produce a true equatorial mounting *only* at the 45th parallel of latitude. However, by means of a "dutchman", this deficiency can easily be overcome. The dutchman introduces an extra bend in the polar axis, so that the polar axis can have the correct tilt. (Making the dutchman is described later in this article.)

The mounting can be put together by screwing the fittings into or onto each other in the shop and then screwing the big bell reducer onto the top of the pier; it would, however, be much easier to assemble the mounting, fitting by fitting, on top of the pier itself. Although here we're dealing primarily with the mounting and only incidentally with the pier, one of the first things you'll have to determine is the height of the pier. The most natural observing position for persons of average height is when the eyepiece is about 52 inches above ground level. In the 45 degree elbow design, the vertical distance between the center of the junction tee and the bottom of the 4x2 inch reducer atop the pier is about 14-1/2 inches. The eyepiece will be about three inches higher than the center of the junction tee, so if you subtract 17-1/2 inches from 52 inches, your result is about 34-1/2 inches, the height of the pier top above the ground. If you plan to use a permanently set pier, you'll want to sink it in the ground at least three feet. For this you'll need a piece of four inch pipe about six feet long, threaded on the upper end. (You can work out the details if you plan a portable pier.)

Obviously, you control the level of the top of the pier by how deep you dig the hole to receive it. But be absolutely sure you have everything right *before* you pour concrete around it: You can't go back to raise or lower the top of the pier if you make a blunder!

Fitting the Pipes Together

All the cast fittings (but not the nipples) will have the vestiges of the parting fins along their central planes where the two halves of the mold come together. The fittings will have to be assembled so all these fins will be in the meridional plane which, in the drawings, is the plane of the paper. You will have to grind in all the joints as you assemble the fittings together, so they will be tight when the fittings are properly lined up. You also must pin them together with setscrews or they will slip loose and get out of line.

Don't expect to screw all those fittings together in an hour or so. Pipe threads, both inside and out, are tapered — not straight like those on bolts and nuts. Pipe joints make up tight when the inside and outside tapers just match, and it's impossible to anticipate what the relative positions of the two pieces will be when this occurs. It is important that the central planes of all the fittings line up at the same time as they make up tight, so you'll need to grind in the joints, one at a time, with grinding compound so that when they're tight, they also line up. To keep the grinding in of subsequent joints from loosening up already lined up and tight joints, it will be necessary to pin each joint, as it gets tight in the right position, with a setscrew. You can drill and tap all the setscrew holes before you start the grinding process (use 1/4-20 screws — the drill size is #7). However, when you drill a radial hole through the end ring of a pipe fitting, you must be very careful when you get almost through to the inside threads. The drill point will break through the bottom of the threads first and, if you're drilling at high speed, you're likely to snap off the tip of the drill. To get around this problem, don't clamp the drill bit tightly in the chuck — make it just tight enough to keep it from turning during the main part of the drilling. Then if you break through the threads and the point of the drill hangs up, the drill will slip in the chuck and not break.

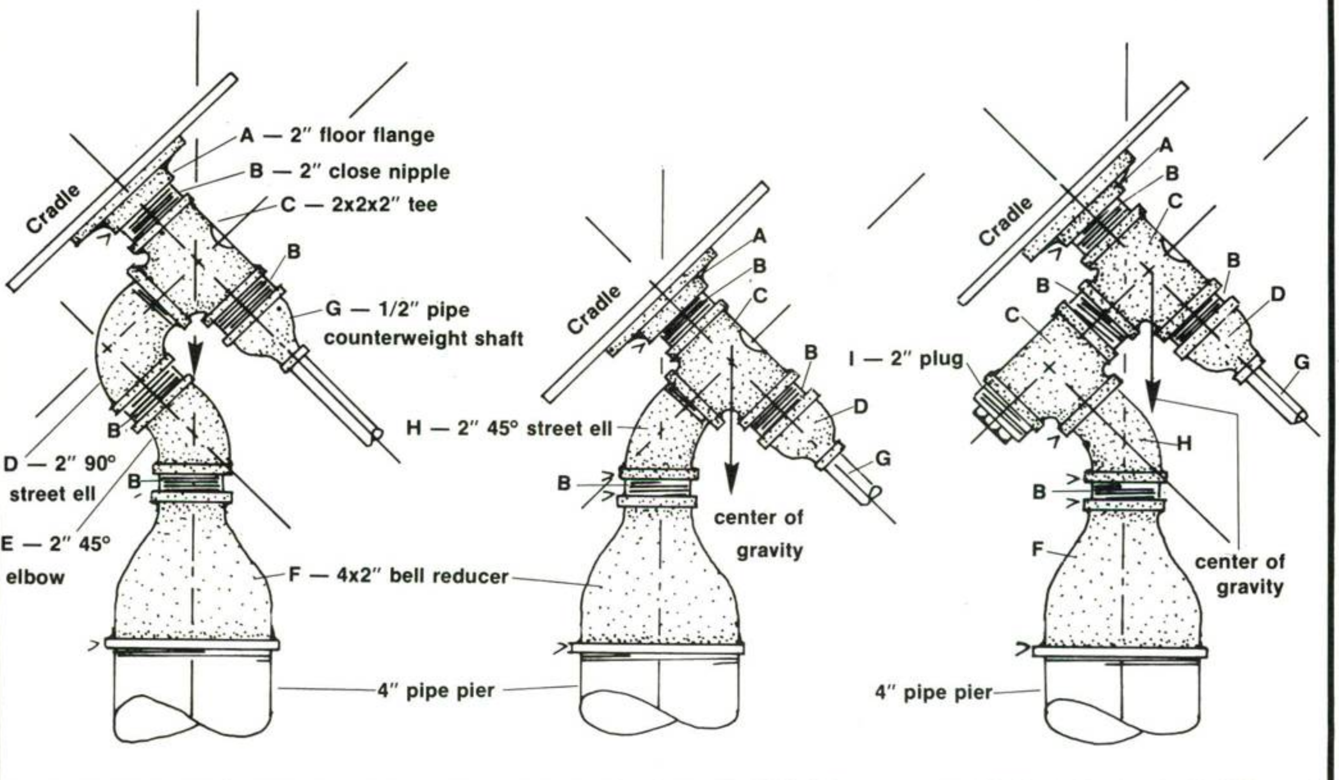
You can, of course, wait until a joint is lined up and tight before you drill the hole for the screw. You can then drill and tap all the way through the end ring and the nipple as though it were solid metal. In this case, you can use an ordinary screw instead of a setscrew.

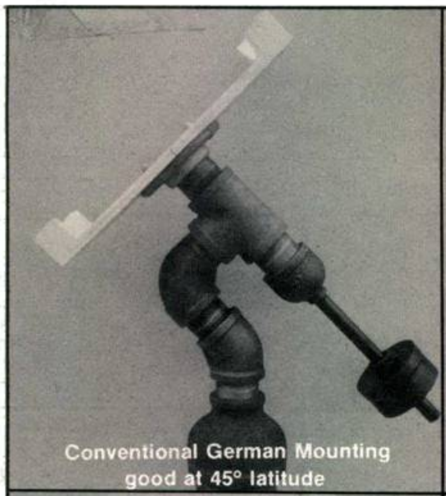
Don't forget that the joint between the outboard end of the declination axis nipple and the floor flange which fastens to the cradle must also be pinned. However, two of the joints do not get locked in place. These are the joints which become the polar axis and the declination axis. These two should be ground in with particular care, so they turn with velvety smoothness. They are the "bearings" of your mounting.

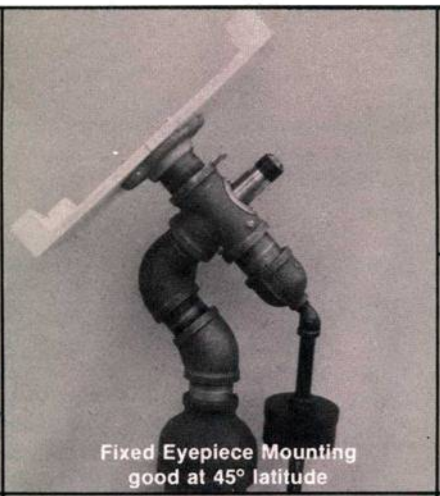
A "Dutchman" Made of Pipe

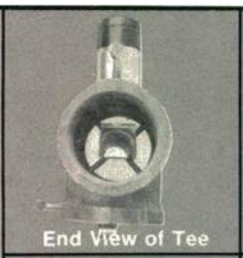
The axis of the joint between the 90 degree street ell and the outlet opening of the junction tee is also the polar axis of the mounting. If you live anywhere between the 43rd and 47th parallels of latitude, don't worry about the slope of the polar axis. A simple mounting such as this one has other limitations which make a slight deviation from the theoretical slope of the polar axis not too important. If you live substantially

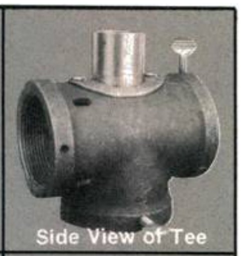
VARIATIONS IN BUILDING A FIXED EYEPIECE PIPE MOUNTING

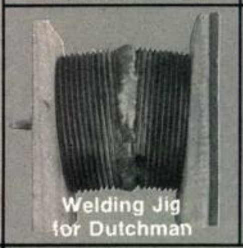


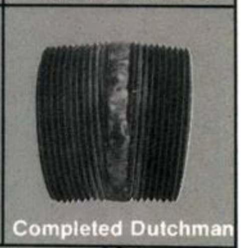

Conventional German Mounting
good at 45° latitude

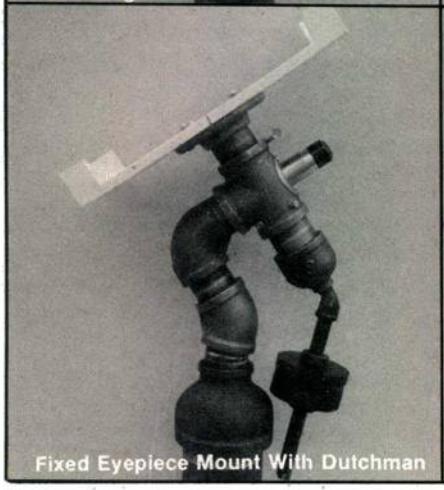

Fixed Eyepiece Mounting
good at 45° latitude

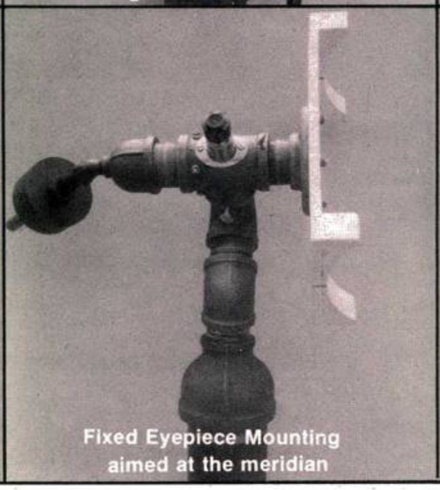

End View of Tee

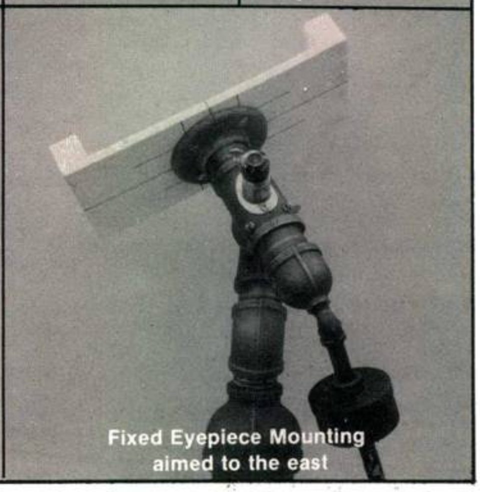

Side View of Tee


Welding Jig
for Dutchman


Completed Dutchman


Fixed Eyepiece Mount With Dutchman


Fixed Eyepiece Mounting
aimed at the meridian


Fixed Eyepiece Mounting
aimed to the east

beyond these limits, and depending upon what you intend to do with your rig, it may be worthwhile to tilt the polar axis enough to bring it into parallelism with Earth's axis. The simplest way to do this is to replace the two inch close nipple between the 4x2 inch reducer and the 45 degree elbow with one which has been sawed apart and then welded back together. The nipple is sawed in two, crosswise, at an angle equal to *half* the difference between your own latitude and 45 degrees; then one end is rotated a half turn and the two pieces welded back together. This puts a deflection angle in the modified nipple equal to the *whole* angle between your latitude and 45 degrees, and throws the axis of the joint below (or above) 45 degrees just enough to make the axis parallel with Earth's axis.

The easiest way to cut the nipple in two is to make a one-time miter box out of scrap lumber. The kerf which guides the hack saw blade is out of square by half the angle between your latitude and 45 degrees. It's best to make the sides of the miter box just far enough apart that the nipple will fit tightly between them. And further, the sides should be clamped against the nipple with C clamps to insure that nothing slips during the sawing.

Use a new blade. The task is just as simple as cutting miters on wooden molding; it just takes longer. After one half has been rotated a half turn, the two should be held together by a bolt through tapered end blocks so nothing slips during the welding job. The photograph of the mounting above shows a nipple which has a 10 degree deflection between the reducer and the street ell. This means the mounting is designed to be installed somewhere along the 35th parallel of latitude (the boundary between Tennessee and Alabama-Georgia).

If you decide you want a true equatorial and are willing to make up a dutchman, do it early. After the big bell reducer is fitted to the top of the pier, this nipple is the next piece to be fitted into place. Be extra careful to get its central plane of symmetry lined up with the other central planes; you won't have the remnant of a casting fin to help you.

The Eyepiece Holder and Eyepiece

We strongly recommend that you limit yourself to one low power eyepiece in a first telescope. For this telescope, the ideal ocular would be a 25mm Kellner. This will give you a magnification of about 48x, which is enough for you to see the phases of Venus, the disk of Mars, the belts and moons of Jupiter, the ball and rings of Saturn, and the craters of the moon; it'll let you split many doubles, and you'll see many of the Messier objects. With only one eyepiece you won't need much range in your holder — only enough to accommodate the visual differences of viewers other than yourself.

Nor will you need an expensive rack and pinion focuser for this first telescope; a simple draw tube arrangement will be quite adequate. For the draw tube you'll need a piece of brass tubing, 1-1/4 inches in inside diameter with a wall thickness of 1/16 inch, and about 1-1/2 inches long. The ID and OD dimensions of tubing are somewhat nominal, so you'll have to check the piece you use. The OD is not too important, but the ID is. If it's undersized, it won't accept the barrel of the eyepiece, and if it's oversize your eyepiece will slide around and not stay in focus. Ideally, the ID should not accept the barrel of the eyepiece until you have lapped both the inside of the draw tube and the outside of the eyepiece barrel with fine abrasive cloth — the finer the better. Strive for a smooth push-pull fit which will stay put where you set it, but which will move in and out without grabbing.

You'll need to design some sort of a saddle to hold the draw tube on top of the junction tee. This can be made of 16 gauge brass cut to an elliptical shape, about 2x2-3/4 inches in size, and curved so it fits snugly on the tee. After you have a good fit, center it on the upper surface of the tee and fasten it in place with a pair of 6/32 machine screws.

Cut a hole in the saddle and in the junction tee to take the draw tube and let the converging cone of rays into the draw tube where they will come to a focus. This can be done well on a lathe, holding the tee by the outlet opening in a universal chuck and cutting the hole with a boring bar. The hole should be a moderately tight fit for the draw tube. Later, almost as the last operation, you can solder or braze the tube to the saddle piece; don't do this, though, until you have had a chance to try out your eyepiece and find out where it focuses.

The Cradle and Tube

The wooden cradle — a plywood body and two concave saddle pieces — looks simple in itself, but it must be accurately made or you'll have trouble when you try to collimate the optics. The two end pieces must be *exactly* alike, and must be mounted *exactly* square with the longitudinal axis of the cradle. The size and location of the hole in the plywood body is not critical — it just has to be big enough to let the cone of light through. The centering of the floor flange which fastens to the cradle *is* critical. The threads in the flange define the declination axis; the saddle pieces define the axis of the main tube. It is essential that the declination axis and the tube axis intersect, and that they intersect at a true right angle. The layout lines to accomplish this relationship are heavy enough to see in the photographs on page 57 . Hold the tube temporarily to the saddles with straps or bands; eventually, however, you may want to fasten it rigidly to the cradle after the rig is collimated.

The declination axis should be about 37 inches from the reflecting surface of the primary mirror. The first diagonal must be located exactly at the intersection of the main tube and declination axis. Support it there by a spider and diagonal holder having capability of adjustment sufficient to deflect the cone of rays exactly along the declination axis. At the intersection of the declination and polar axes (which is located inside the junction tee), there must be a second diagonal to deflect the cone of rays upward through the draw tube. A 25mm right angle prism (rather than another flat mirror) is best for this diagonal. This prism must be supported inside the junction tee in such a way that it turns with the polar axis but does not turn with the declination axis. There is an opportunity for a little originality in devising this supporting structure. One method, which has been used successfully, is to make a miniature spider and diagonal holder that is mounted inside the tee on the side opposite the telescope tube. Since this support system is not in the path of the incoming light (as is that for the first diagonal), you can use thick rods instead of thin vanes for the spider. The holes for the ends of the spider rods can be slightly oversized slots to allow for adjustment. The prism must throw the axis of the cone of rays exactly upward through the draw tube, along the polar axis.

Counterweighting

A fixed eyepiece mounting requires some special attention to counterbalancing because you cannot slide the tube back and forth in the cradle so it will balance itself about the declination axis. The simplest way to balance this pipe fittings mount is with two counterweights — one on the tube, and the other on the declination axis. The one on the tube should be ring shaped and mounted in front of the open end of the tube (see the drawing on page). Instead of mounting the other counterweight on an extension of the declination axis, you can "bend" the shaft by inserting a 45 degree fitting between it and the 2x1/2 inch reducer in the "off" side of the junction tee. This arrangement does keep the weight and shaft out of the observer's way when it is in the meridional plane.

The best way to acquire a ring type counterweight is to have a metal fabricating shop make one for you. Have them roll a piece of bar stock 31-1/2 inches long into a 10 inch diameter ring. By choosing the size of the bar stock, you can get almost any amount of weight in the ring that you need. Steel weighs 0.28 pounds per cubic inch. Suppose you have the ring made up from 3x1/2 inch bar stock. This size would weigh 3 x 1/2 x 31-1/2 inches x 0.28 pounds per cubic inch, or slightly over 13 pounds.

If you weigh every component part which produces a torque about either axis, and measure the distances of these components from each axis, you can calculate how heavy each counterweight will have to be reasonably well. It may be easier to use junk weights at first, and then do the balancing by the "cut and try" method. Once you know how much weight you need, have finished weights made up. If you do it this way, make the shaft and the outriggers plenty long to start with — it's easy to cut off the excess, but not so easy to put on a piece.

Collimating the Optics

If you have done your work well, you ought to have little trouble in collimating this pipe fittings-stationary eyepiece telescope. Install the optical elements one at a time, beginning with the primary mirror, and be sure that each is properly lined up before you put the next element in place. If you don't and one or another is out of line, you'll find it difficult to tell where the trouble is. Get the main mirror lined up with the tube axis first; then install the spider and first diagonal, making sure the elliptical mirror is centered in the tube as well as on the declination axis; then get the diagonal tilted so that when you sight down the declination axis, the diagonal seems centered on the main mirror. When you have this right, install the prism inside the junction tee. You won't have much trouble centering the prism, because the prism is somewhat oversize and will field all of the cone of rays unless you have it in there terribly crooked. Rotate the prism around the declination axis until the face toward the draw tube is square with the polar axis; when you get this accomplished, you should see the prism, the elliptical diagonal, and the main mirror images all centered on each other.

One of the easiest and best ways to check the alignment of this train of mirrors is to use a 1/4 inch dot at the geometric center of the primary mirror and a 1/16 inch dot at the geometric center of the elliptical diagonal. You won't need a centering dot on the prism — you can do this well enough by eye. Place a centered peephole in the draw tube in place of the eyepiece; when you have all three optical surfaces properly aligned, the collimating dots on the two mirrors and the image of the pupil of your eye will all coincide.

About the only place where you'll have room for trouble is in accurately "squaring on" the telescope tube with the declination axis. If the two saddle pieces of the cradle are not identical and are not both squared and centered on the cradle axis, the telescope will lose alignment when the tube is turned around the declination axis. Be prepared to go back and loosen the bands which hold the tube in the saddle pieces, and then insert shims (thin strips of metal) between the tube and one or the other saddle until — by trial and error — the joint is brought into exact perpendicularity. (This is why you were advised not to permanently fasten the tube to the cradle until collimation had been accomplished.) When this adjustment is completed, the optical alignment will remain unchanged regardless of what direction the telescope is pointed.

There is a small loss of light with this optical system because there are three reflecting surfaces as compared with only two in a conventional Newtonian. But after you've found what you are looking for, you'll have a much better view of it comfortably seated on a stool than you would get if perched on tiptoes on a stepladder!

ASTRO-NEWS

Latest News From the World of Astronomy

Uranus Puzzles Astronomers

The planet Uranus, recently discovered to possess rings (see Stellar Frontiers), has presented new problems for astronomers. One has to do with the rings themselves and a possible sixth satellite, while the other arises from radio observations of the seventh planet.

Major changes occurring deep in the atmosphere of Uranus have been discovered by two radio astronomers at NASA's Jet Propulsion Laboratory in Pasadena, Calif.

Dr. M. J. Klein of JPL's Planetary Atmospheres Research Section and Dr. J. A. Turegano, a visiting research associate at JPL from the University of Saragosa (Spain), have found that radio emissions from deep in the Uranian atmosphere have become 30 percent stronger in 10 years.

Klein and Turegano, who made their observations with NASA's 210 foot (64 meter) radio antenna at Goldstone, Calif., said the radio waves, which penetrate the dense clouds on Uranus, originate deep in the atmosphere where pressures are thought to be more than 10 times greater than at Earth's surface.

The observations confirm the astronomers' earlier discovery of changes in the atmosphere.

They believe their results can be explained if Uranus' atmosphere is either warming up or becoming clearer to the passage of radio waves. But it's hard to believe that the temperature so deep in a planet's atmosphere could become 30 percent warmer in only 10 years. A similar change on Earth would raise our average air temperature above 250 degrees Fahrenheit (120 degrees Celsius)!

It's more likely, they said, that the change is related to the planet's unique orientation. Unlike any other planet, Uranus spins on its side as it orbits the sun. Every 84 years (the length of one Uranian year), the sun shines directly on the north pole of Uranus; 42 years later the northern hemisphere is dark and the south pole points sunward.

The north pole is now turning toward the sun after 42 years of darkness. It will point directly at Earth (and the sun) in 1987.

Radio emissions from Uranus' deep interior are probably blocked by ammonia gas in the planet's atmosphere. Klein and Turegano have suggested that ammonia might be preferentially depleted in the polar regions of the planet — either by convection currents or chemical reactions. If this were the case, then at the present, radio telescopes would be measuring hotter temperatures, deeper in the atmosphere, than were measured 10 years ago when the planet's polar orientation to the sun was somewhat different.

Theoretical studies are now going on to determine how radio measurements may be related to global changes in the climate, weather patterns and chemistry of Uranus' atmosphere. Those studies aid in development of general theories about planetary atmospheres, which in turn are applied to specific studies of Earth's atmosphere.

Current studies of the radio temperatures of Uranus are important in understanding the origin of the solar system, because recent results suggest that Uranus — unlike Jupiter and Saturn — has more than its expected share of elements heavier than helium. This conclusion suggests that a chemical imbalance occurred in the outer regions of the solar system billions of years ago when it was forming.

The newly discovered rings of Uranus have led to a prediction of an undiscovered sixth satellite. Such a satellite could account for the position of the rings around the planet. Astronomers have assumed that the particles making up the thin rings are locked into position by gravitational interactions (so-called *resonances*) with the planet's five known satellites. But exactly how this mechanism works has remained uncertain.

Now planetary scientist G. A. Steigman of the University of Hull (England) has shown that three of the

Uranus *continued on page 62*

Space Shuttle Delayed

The first launch of the Space Shuttle has been pushed back another three months, to Sept. 28, 1979.

In addition, NASA will request another $100 to $200 million to keep the program on track. Without the supplement, officials say the first flight will slip another six months to a year and cost $1.5 billion more.

"All the elements of the program have had problems," said Dr. Mike Malkin, director of Shuttle development. "It's relatively uniform across the board."

The main engine had been pacing the entire program, but Malkin said problems with the orbiter, external tank and solid rocket booster were contributing to the delay and extra cost.

The Shuttle is a reusable spaceplane being developed for operations in the 1980s. It will be able to carry up to 65,000 pounds of payload, and fly 100 missions each.

While some people regard it as just another space extravaganza, NASA says it is the most important and flexible tool space scientists will have in the 1980s and 1990s.

The Shuttle program has had difficulties since it was started. Government accountants forced NASA to cut the size, and debates in Congress nearly killed its funding. Shortly after the main engine contract was awarded, the General Accounting Office suspended work on it while it probed claims that the award was made to the wrong firm. (The GAO

Shuttle *continued on page 64*

Powerful Interferometer Slated For Owens Valley Observatory

The world's most powerful interferometer at millimeter wavelengths will begin observations in 1980 at Owens Valley Radio Observatory, 200 miles north of Los Angeles. A combination of three 34 foot (10.4 meter) diameter receivers will provide resolutions of one second of arc at 2mm wavelengths, allowing astronomers to probe ever more deeply into quasars, galactic nuclei and clouds of interstellar dust and gas.

One radio telescope is now in operation and a second will be installed this year. Tentative plans call for the radio "dishes" to move along a T-shaped track, one kilometer long and 500 meters across. Owens Valley currently has two 90 foot (27 meter) and one 130 foot (40 meter) radio telescopes for work at centimeter wavelengths.

Interferometers are arrays of radio telescopes whose collected radiation is electronically combined into one signal. The greater the distance between telescopes, the higher the obtainable resolutions.

The California Institute of Technology, which operates Owens Valley, also plans a submillimeter radio telescope for a high altitude site, possibly Mauna Kea in Hawaii. Due for completion this year, the 34 foot dish will scan the heavens at 1/3mm — about the shortest radio wavelengths detectable on Earth.

Physicist Robert Leighton built the parabolic receivers for Owens Valley in the "dish factory" at Caltech. The dish factory is the same cavernous laboratory in which the 200 inch mirror for the Palomar optical telescope was ground and polished over 30 years ago. The walls and ceiling of the building are lined with two feet of cork to keep the inside temperature relatively constant. Constant temperatures are also helpful in accurate dish making, because radio telescopes for millimeter work require extremely smooth and precisely shaped parabolic reflectors.

Leighton designed the 34 foot receivers so that they can be taken apart, trucked to Owens Valley, and then reassembled with an insignificant loss of parabolic accuracy. Careful machining and tolerances down to 1/10,000 inch allow the dish supports to fit together without welding like an erector set. NASA is considering Leighton's techniques for use in building complicated structures in space.

The Owens Valley interferometer is one of several new radio telescopes built to study short radio waves. The University of Massachusetts now operates a 45 foot (13.5 meter) receiver for millimeter observations (see Astro-News, December 1977), and the British Science Research Council plans a 50 foot (15 meter) dish in Hawaii (see Astro-News, November 1977). The French and Japanese also propose to build interferometers to study this spectral range.

Why this sudden interest in millimeter astronomy? "Probably the main reason has been the unexpected discovery of complex interstellar molecules whose characteristic spectral lines are at millimeter wavelengths," explained Alan Moffet, director of the Owens Valley Radio Observatory. Since 1963, over 40 different molecules have been found, most of them in dark clouds near Orion's "belt" as well as the galactic center.

"Frankly, astronomers have been surprised by the number and complexity of interstellar molecules that have turned up," Moffett said. Both inorganic and organic molecules have been identified, some containing up to 11 atoms. But no amino acids — the direct building blocks of life — have been detected to date.

Searches for molecular lines, however, are best pursued by individual radio telescopes, Moffet noted. The high resolutions afforded by the Owens Valley interferometer will be more effective mapping regions of star formation in dark clouds of gas and unusual extragalactic sources.

"Little is known about the causes of millimeter radiation in certain quasars and galactic nuclei," said Moffet. "Studying their short wave structure may help reveal their power sources.

"Once the interferometer is operational, one thing is certain," Moffet continued. "We'll uncover phenomena no one's ever thought about. The most interesting discoveries can't be anticipated."

The $3.5 million Owens Valley project is mainly funded by the National Science Foundation. The submillimeter facility is supported by the Kresge Foundation.

Dr. Eleanor Helin, discoverer of a new class of asteroids whose orbits are smaller than Earth's, is shown above with the discovery photograph of Ra-Shalom, the newest member of the group (see Astro-News, November, 1978). Caltech president Marvin L. Goldberger is at left. The provisional designation for Ra-Shalom was 1978-RA, a code indicating the year and time of year the asteroid was found. This designation suggested at once the name Ra, the ancient Egyptian sun god who symbolized enlightenment and life. By adding the Hebrew greeting shalom, meaning peace, the name, Ra-Shalom was chosen by Helin to commemorate the promising conclusion of the Camp David Conference on peace in the Near East, and to stand as a symbol of the universal hope for peace. The discovery photograph with an accompanying plaque was presented by Helin to Israeli Prime Minister Begin at the conclusion of the Camp David Summit. Caltech photograph.

Afro-American Skylore Studied

A project to design sample planetarium programs exploring the skylore of Africa, and that emerging later on this continent among Afro-Americans during the period of slavery, has been approved by the National Endowment for the Humanities. W. Russell Blake, director of the Plymouth-Carver Planetarium, is in charge of the project.

Blake has appealed for assistance and suggestions in the identification of myths, legends and folktales which relate to astronomy and skylore. Also of possible astronomical import are proverbs, rhymes, songs, games, dances, arts and crafts, religious rites and beliefs, and time-keeping devices. All the African and Afro-American lore collected must relate directly or indirectly to the sky and its celestial objects, to the creation of the cosmos, or to natural phenomena caused by Earth's position and motion in the solar system.

Anyone who could contribute such information is asked to contact:

W. Russell Blake, Director
Plymouth-Carver Planetarium
Long Pond Road
Plymouth, Mass. 02360

Building in Space

The company that built the Apollo Lunar Module has demonstrated a device that could one day build large structures in space.

"It's really an erector set," said Hugh Dudley of Marshall Space Flight Center in Huntsville, Ala. "It just opens all sorts of possibilities."

The Grumman Aerospace Corp. of Bethpage (N.Y.) built the prototype automatic beam builder under an $650,000 contract to the Marshall Center.

"It was conceived as a way — not the only way — to meet large area space construction in a reasonable period of time," Dudley said.

Although giant solar power satellites are the most likely to use them, such beams could be used by in-orbit gravity wave experiments or for a large pinhole camera to examine the sun.

Such structures — even for astronomical observations — would be hundreds of yards, perhaps several miles, across.

Their weight, though, would be surprisingly light. Dudley said that a 500 foot beam would weigh only 425 pounds and could be made in about three hours. The beams would be 4-1/2 feet on a side and made of aluminum about the same thickness as that used in roof gutters.

In fact, roof gutter construction was a partial inspiration for the beam builder's designers. The longitudinal members are stored in three rolls of aluminum stock. They are cracked through the same type of rollers used in making roof gutters on-site in the back of a truck. Three additional magazines hold strip stock to be welded as crosspieces.

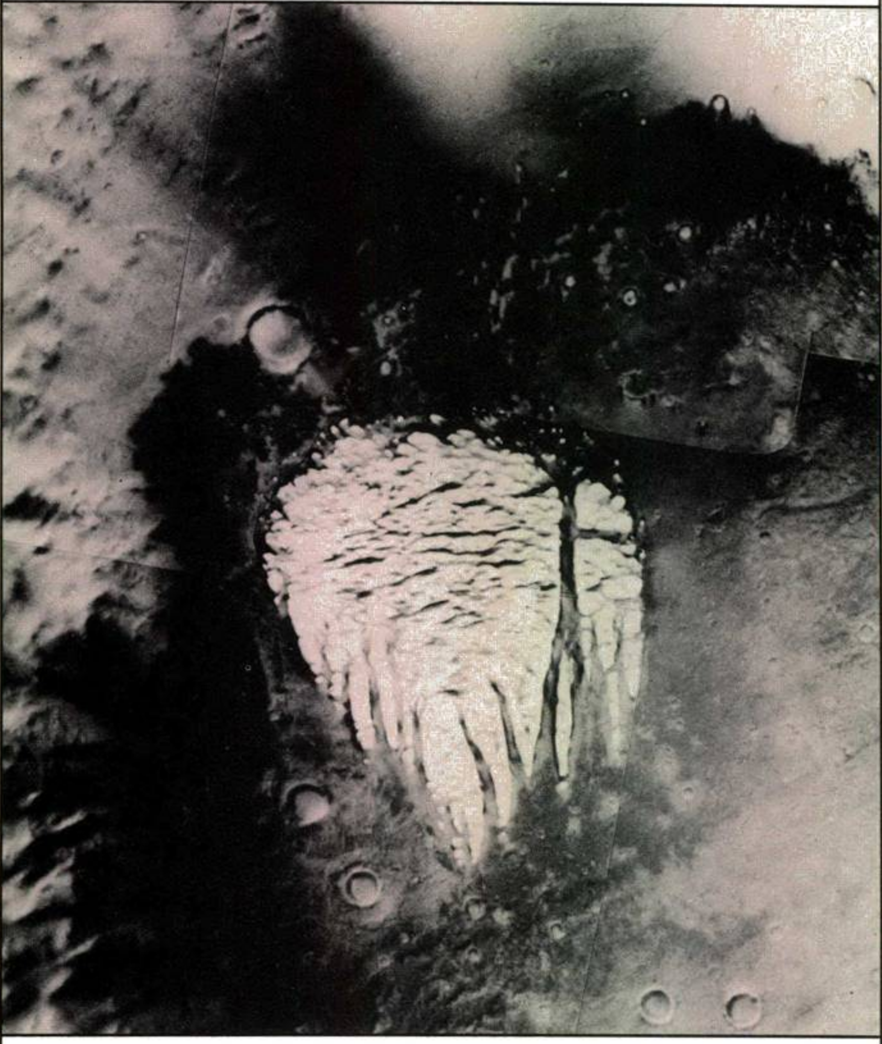
The beams would be built automatically, but they would be handled and welded to each other by astronauts.

Dudley said, "There's not enough money to expect to do everything in an automated mode just because we're in the space age."

The Grumman prototype built a beam only 40 feet long, and will be used in testing the concept at the Marshall Center. Dudley said it could be used in space with substantial modifications.

A space demonstration may come in 1983. It would build a prism shaped structure 100 feet long and 33 feet on a side.

A Martian Mystery



This strange feature found inside a Martian crater, the only such feature seen on Mars, will be the subject of study for scientists on the NASA Viking mission. Although it has been nicknamed White Rock, its composition is unknown. Scientists, however, have determined because of its equatorial location, that it is not ice or snow. The feature is 8-1/2 by 11 miles (14 by 18km) in size.

First seen in 1972 by Mariner 9, White Rock was photographed at this higher resolution by the Viking Orbiter on Sept. 1, 1978.

The highly reflective feature is in the bottom of a large crater about 58 miles (93km) in diameter, located at 8 degrees south latitude, 335 degrees west longitude.

Nancy Evans of the Jet Propulsion Laboratory has been named principal planetary geology investigator to study the White Rock formation in an attempt to understand its composition and the history of its formation.

The pictures for this mosaic were taken from an altitude of 705 miles (1.135km) above the Martian surface, and resolution in the Viking images is 472 feet (144m).

New Supernova Account Found

A new eyewitness account of the supernova of 1054 that gave rise to the Crab nebula has been uncovered by scholars, proving for the first time that this celestial cataclysm was seen by astronomers in the Near East as well as in the Orient. Until now, the lack of known observations of the Crab supernova from Eurpoean or Arabic astronomers has been a puzzle.

Western astronomers realized last century that Chinese and Japanese records contained accounts of a bright new star seen in Taurus in 1054. In 1921, American astronomer John C. Duncan discovered from a comparison of photographs taken several years apart that the Crab nebula in Taurus, the remnant of a supernova explosion, is apparently expanding at a rate which implies it was born about 900 years ago. But not until 1928 was the connection between the occurrence of the Chinese "guest star" in Taurus and the origin of the Crab nebula drawn, by famed cosmologist Edwin Hubble. Since then, astronomers have come to accept that the object viewed by the Chinese was the supernova that must have given rise to the Crab nebula.

According to Oriental records, the new star rivaled Venus at its maximum, meaning that it became as bright as magnitude -4 or -5. For 23 days the brilliant object was visible in the daytime, and it was observed for over a year in total, so it certainly should not have escaped the attention of anyone with the slightest knowledge of the sky. Recently, astronomers have found a number of cave drawings by native Americans in the southwest states which may represent the passage of the crescent moon near to the Crab supernova — which computations show occurred on July 5, 1054, as the star reached its maximum brightness.

But no records of the supernova were found from European or Arabic astronomers. One suggested reason was that the entire area of Europe and the Near East was dogged with persistent clouds while the supernova was at its brightest, which seems implausible. Another explanation is that the object went unrecorded because of the reluctance of astronomers of the day to accept that such unscheduled events could mar the heavens. But this cannot be supported either because of the existence of Arab records of the supernova of 1006, as well as widespread observations of several comets around that time, such as the appearance of Halley's in 1066.

Now, Kenneth Brecher of the Massachusetts Institute of Technology and Israeli scholars Elinor and Alfred E. Leiber have drawn attention to an apparent sighting of the Crab supernova by an Arab scientist, Ibn Butlan, who was a physician working in Constantinople at the time of the event. Butlan made particular note of the outburst because it coincided with a major outbreak of disease and famine. This had astrological significance because physicians of that time were concerned with the presumed effects of celestial events on the health of humans.

Ibn Butlan's hitherto overlooked account is contained in his biography in an encyclopedia of physicians compiled around 1242. The medieval biographer said he copied a report in Ibn Butlan's own hand, part of which says in translation: "One of the well-known epidemics of our time is that which occurred when the spectacular star appeared in Gemini in the year 446 H [between April 1054 and April 1055]". The report goes on to note that hordes of people died in Constantinople that autumn, and 14,000 were buried in a churchyard after all other cemeteries had been filled.

The following year the epidemic spread to neighboring areas. Ibn Butlan said: "As this spectacular star appeared in the sign of Gemini which is the ascendant of Egypt, it caused the epidemic to break out in Fustat (the old part of Cairo) when the Nile was low, at the time of its appearance in the year 445 H (between April 1053 and April 1054)." This second date is evidently a mistake. Another account by Ibn Butlan confirms that the Cairo famine began in 445 H but increased the following year, which was the year the star appeared and the hordes of peoople were buried, so that the year 446 H was really the one in which the star appeared. Curiously, a similar error, this time of a month, occurs in a Japanese account of the supernova.

Ibn Butlan was particularly struck by the stellar outurst, for he said that Ptolemy had predicted "woe to the people of Egypt" when a comet appeared threateningly in Gemini (ignoring the fact that the object was a new star, not a comet)! But the Crab nebula is in Taurus, whereas Ibn Butlan mentioned a new star in Gemini; what can we make of this apparent discrepancy? Note that he specifically referred to the sign of Gemini rather than the constellation, meaning he was talking astrologically, not astronomically. By 1054, the effect of precession, caused by Earth's wobble in space, had carried the astrological sign of Gemini into the part of Taurus containing the Crab nebula.

Since Ibn Butlan noted that the supernova was followed by an epidemic that same autumn, the star must have appeared in the summer of 1054, consistent with Oriental records which place its greatest brightness around July 4 — a fitting date for such a celestial firecracker.

Uranus *continued from page 59*

rings can be explained by the combined actions of the satellites Miranda and Ariel. But to explain the existence of two other rings by this resonance process requires the existence of one other, undiscovered satellite of Uranus.

This sixth satellite would orbit the planet every 24 hours 35 minutes at a distance of 105,200km, making it the closest satellite to Uranus. Since it has so far escaped detection, it must be as faint as magnitude 18 to 20 — which, assuming an albedo (ability to reflect sunlight) similar to that of Miranda, implies a diameter of 100km or so.

Steigman has calculated that resonances involving the sixth satellite and the five known satellites of Uranus can account for all the observed rings of Uranus, including the three or four new rings discovered at an occultation on April 10, 1978. The sixth satellite might itself have accreted from a former ring.

The rings of Uranus are now known to be rocky in composition, but according to an analysis of the motions and resonances of the three innermost known satellites performed by another researcher, Miranda, Ariel and Umbriel may be icy.

Dr. Richard Greenberg of the Planetary Science Institute in Arizona explained that the observed resonances in the orbits of the inner satellites should enhance their mutual gravitational effects. Measurable irregularities in one or another's motion should be apparent.

Such irregularities have not been observed, and therefore the satellites must have small masses. But they are fairly bright, so their albedos must be high and their densities low. A good guess, according to Greenberg, as to a kind of material with such properties in that part of the solar system is ice. The inner satellites would thus be quite different from the rings, which are very dark, and the satellite Oberon, a dark, dense body.

Study of the planet Uranus has undoubtedly only begun, and the questions are increasing. Planetary scientists are more and more hopeful that the Voyager spacecraft now nearing Jupiter and due to rendezvous with Saturn later will indeed survive long enough to return data about Uranus in 1986.

European Astrolab Mission Planned

The West German Federal Ministry for Research and Technology is developing a Spacelab mission dedicated solely to astrophysics.

Called Astrolab, it will use two twin Spacelab pallets to support various experiments. The pallets are open platforms for experiments that need to look into space or cannot be housed in a pressurized Spacelab module.

Candidates for experiments include an infrared telescope, a wide angle ultraviolet camera, an extreme ultraviolet/soft x-ray telescope, an x-ray telescope, a scintillation counter array, and a double Compton-effect telescope.

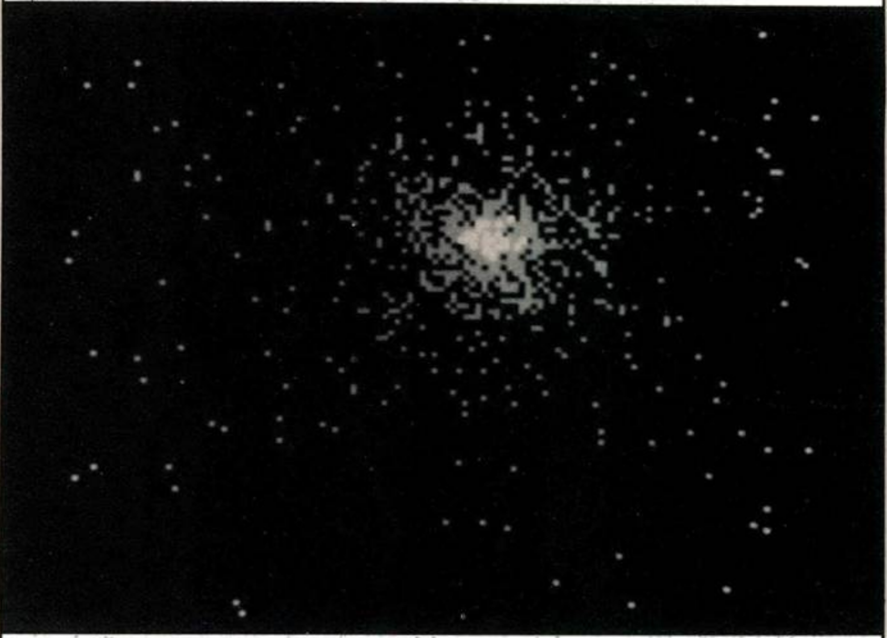
Experiments that do not fly on the first Astrolab mission could be selected for later flights.

More than 75 European scientists responded to Germany's call for proposals for the mission. Astrolab will probably fly in 1983.

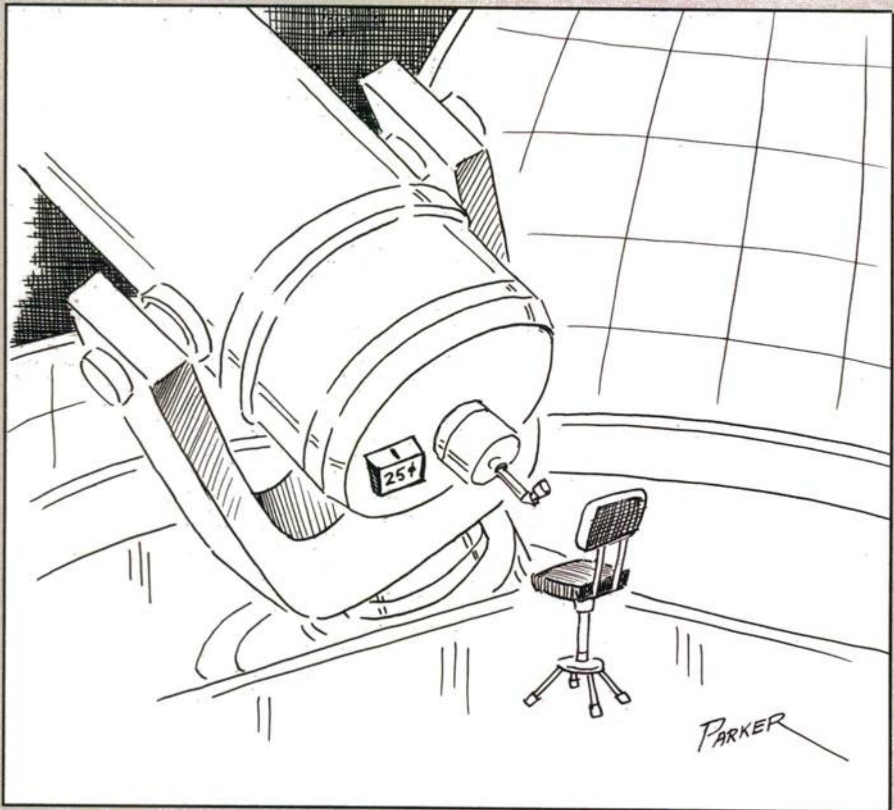
Also being developed under separate Spacelab astronomy programs in Europe are an x-ray spectro-polarimeter and a grazing incidence solar telescope.

West Germany is also developing a Spacelab flight for materials processing and communications experiments. The European Space Agency is developing two Spacelab missions for an atmospheric physics flight and a multidiscipline flight.

First HEAO X-ray Picture



This is the first complete x-ray picture of a star. The first target imaged by NASA's second High Energy Astronomy Observatory (HEAO-2) was Cygnus X-1, believed to be a binary star in which one of the components is a black hole. HEAO-2, which has been christened the Einstein Observatory in honor of the 100th anniversary of Albert Einstein's birth, is now fully operational in its near perfect Earth orbit after a flawless launch. Carrying the largest x-ray telescope ever built and a variety of sensitive instruments, the Einstein Observatory will maneuver and point for long periods of time at selected x-ray sources already identified by its predecessor HEAO-1 (which has no imaging capability). In the photograph above, the dots represent x-rays. The raw data includes scattered background radiation from other sources; only the small white central portion represents the x-ray counts received from the star itself. The extraneous counts will eventually be removed by computer processing to produce a true picture of Cygnus X-1. NASA photograph.



Seasat Mission Ends

After nearly a month of attempts to reestablish contact with Seasat, NASA's experimental oceanographic satellite, project officials declared the mission formally terminated. Seasat was launched June 26, 1978, and contact was lost with the satellite on its 1,502nd orbit of Earth on Oct. 9, 1978, when a so-far-unexplained short circuit drained all power from the batteries.

Data collected during the spacecraft's 106 day lifetime indicated that the primary objectives of the mission were probably achieved, despite the early failure. Project officials expect the tasks of data processing and analysis to take more than 1-1/2 years.

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Shuttle *continued from page 59*

supported NASA's decision.)

The first delay came as a result of Congress wanting the peak funding, the period when the cost would be highest, reduced. So, the first launch was pushed back from 1978 to 1979. Then, development problems with the main engine forced NASA to slip from its internal target of March 1979 to June 1979, the official date.

Finally, problems with the whole system forced NASA to announce in late September that Sept. 28, 1979 would be the new launch date — if no more problems arise.

Ironically, this came just as the main engine test program was hitting its stride. Early in 1978, the main propulsion test article was successfully fired four times (from 1 to 100 seconds). This is a working model of the three engine cluster, plumbing, and external tank with 1.6 million pounds of liquid hydrogen and liquid oxygen.

In March, a National Research Council report verified that there was nothing basically wrong with the design, but did recommend that a new test stand be activated and a standby design be drawn up for the high pressure liquid oxygen pump.

In the summer and fall of 1978, testing moved ahead at high speed. More than 25,000 seconds of test time had been accumulated when NASA announced the new delay (70,000 seconds is the minimum required for first launch), including 5,000 seconds on a qualification engine almost identical to flight hardware.

Additional tests proved the engine could be throttled, swiveled, and run for 13 minutes 40 seconds in case of emergency (8 minutes 40 seconds is the norm). Two mishaps — a fire and a hot start — turned out to have minor origins in probe installation and pump assembly.

Each engine must endure 50 flights before overhaul, with pressures as high as 2-1/2 tons per square inch and temperatures that would melt iron inside the combustion chambers. Thrust is up to 475,000 pounds.

"But all these problems don't come for nothing," Malkin said, and they constitute 10 percent of the supplementary request that will be made. Part of that cost comes from the extra test stand recommended in the NRC report.

The orbiter, the part which resembles a jet fighter and which will fly back from space, is causing most of the problems now.

"It takes longer to put that thing together than we thought initially," Malkin said. Orbiter 102, which will be used in the first two years of Shuttle flights, is in final assembly at Rockwell International's Palmdale, Calif. plant. It is to be delivered to Kennedy Space Center by March 1.

Malkin said the problem is mainly with the reusable heat shield, a fragile silica tile. Strikes at Lockheed Missiles and Space Co. "had a lot of effect on what got done", Malkin said.

Production is back on schedule, but installation is going slow. The tiles have been applied to the relatively flat belly and sides, but there have been problems on the nose curves and where wing and fuselage meet.

There are also six-month delays in delivering flight computer programs and in starting full operations with crew and electronics simulators at Johnson Space Center in Houston.

Malkin said that, all told, the orbiter accounts for 53 percent of the budget supplement.

The external tank and solid rocket boosters have lesser problems to match their lesser sophistication.

The tank is an insulated throwaway aluminum can that feeds the main engines during launch. It is slightly overweight, a problem which engineers hope to correct after in-flight tests give them better measurements on loads. The insulation is also being changed to add a cork-rubber base under the latex foam.

The boosters provide up to three million pounds of thrust for two minutes. Each will be recovered after splashdown and used 20 times.

Malkin said there have been problems in every part of the booster. Production problems with McDonnell Douglas delayed the forward and aft structural skirts that carry the booster's loads.

The main problem was postponement of the third booster demonstration firing. Extra insulation had to be added in areas where engineers were concerned that the propellant might burn through the steel casing.

The firing on Oct. 19, 1978, which included a flight type nozzle and gimbaling system, went perfectly, though. Four more firings are planned before the first Shuttle launch. Malkin said the tank accounts for 13 percent of the budget supplement, and the booster is 18 percent. The remaining 6 percent goes for changes at Kennedy Space Center.

Other Shuttle tests are also running well. The launch vibration simulations entered their second phase — liftoff — last October. For the first time, orbiter, tank and boosters were brought together. The tests are taking place with the orbiter Enterprise at Marshall Space Flight Center in Huntsville, Ala. Marshall is also conducting stuctural tests on the tank and booster. Booster parachute tests were successfully concluded earlier last year.

Malkin said the supplementary request will be made with the fiscal 1980 budget in January. If it is refused, he said it will cost up to $1.5 billion when NASA is forced to dip into production funds.

Congressmen have not been enthusiastic about the supplement, but indicate it will be granted.

"Basically, I think the committee feels that they have done a good overall job," said Rep. Don Fuqua (D-Fla.), chairman of the House Space Committee.

Galaxy Found to be Young

An astronomer has reported that the Large Magellanic Cloud, one of our nearest neighbor galaxies, may be much younger than our own galaxy. Dr. Harvey Butcher of the Kitt Peak National Observatory said this would contradict a general belief that all galaxies were formed at approximately the same period early in the history of the universe — between 10 and 15 billion years ago.

His conclusion is based on the finding that the most ancient stars in the Large Magellanic Cloud are nowhere near as old as the oldest stars in the Milky Way.

"Although there appeared to be stars present with a great variety of ages, suggesting a history of more or less continuous star formation, the oldest stars found in significant numbers seemed to be much younger than the oldest stars in our galaxy," Butcher said. "The first look at any new problem can be misleading, however. Before this unexpected new result can be accepted as established, it will be necessary to verify it using several different lines of evidence."

The Large Magellanic Cloud and its companion, the Small Magellanic Cloud, are two hazy areas in the sky discovered by Ferdinand Magellan's crew during his historic voyage around the world between 1520 and 1522. Too far south to be seen in the United States or Europe, the clouds are now known to be galaxies — in fact, our closest galactic neighbors (at a distance of approximately 200,000 light-years).

For his study of the stars in the Large Magellanic Cloud, Butcher used the 158 inch (4m) telescope at Cerro Tololo Inter-American Observatory near La Serena, Chile.

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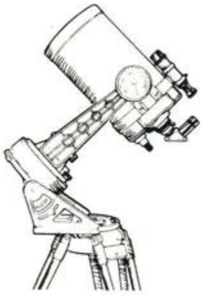

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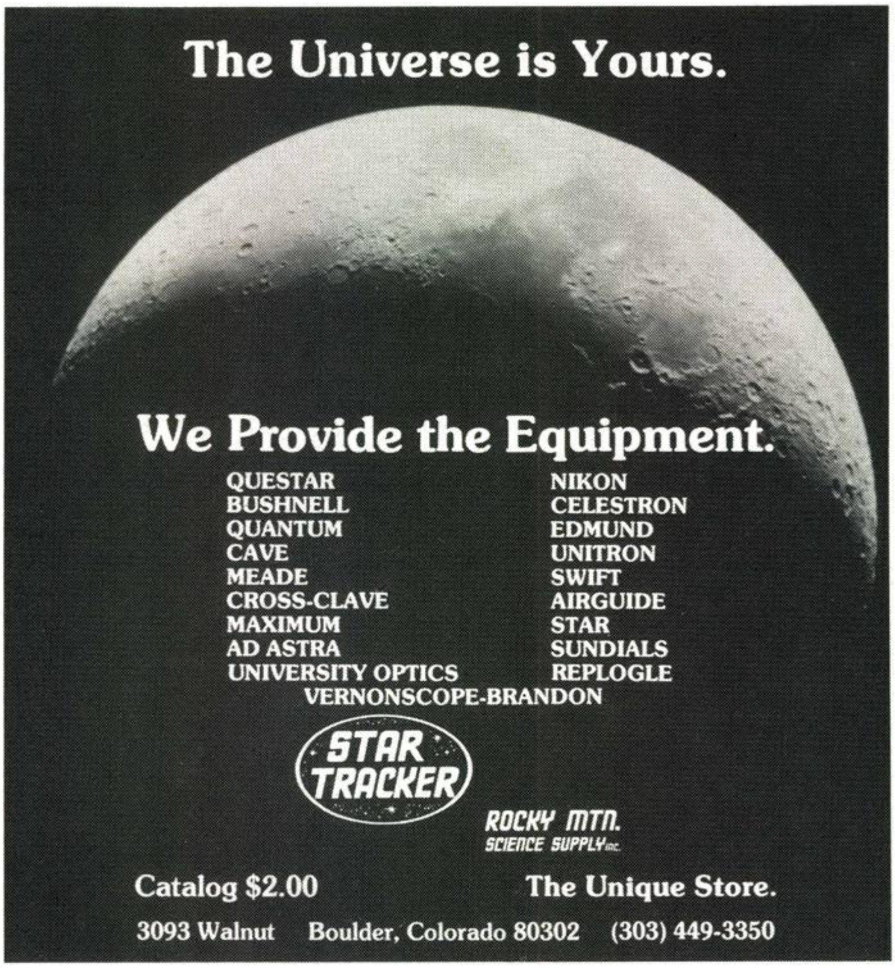

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INFORMATION WANTED — Professional social scientists to respond to a survey on social science community's interest in space utilization concepts such as SPS, orbital factories, communication satellites, LANDSAT. Write The Space Utilization Team, The Graduate School, Georgetown University, Washington, D.C. 20057.

INFORMATION WANTED — Circuit diagrams, components lists for building drive corrector with lunar, planetary and sideral rates. Prefer with capability for adjusting both axes. Also plans for built-in or separate AC/DC converter. Write J.H. Wallingford, 3714 Fallen Timber Dr., Louisville, KY 40222.

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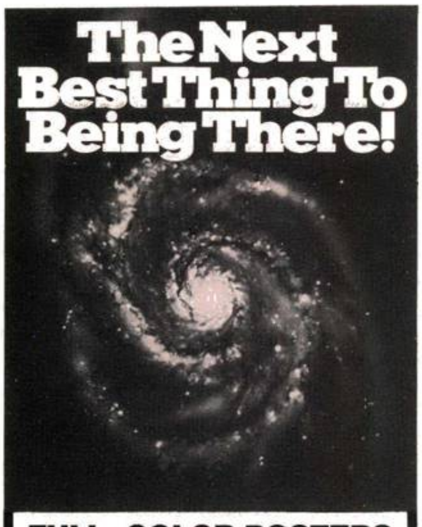
ANNOUNCEMENT — The San Diego Astronomical Society meets on the 3rd Friday of each month at the Reuben H. Fleet Planetarium at 7:30 p.m. The general public is invited to attend. For information, contact Lew Dallas, 462 Oaklawn Ave., Chula Vista, CA 92010. Phone (714) 422-7094.

ANNOUNCEMENT — Do you live north of Pittsburgh, and don't want to drive into the "Smokey City" to attend meetings? Check out the Beaver Valley Astronomy Club. Write BVAC, c/o Doug Gilchrist, P.O. Box 493, Beaver, PA 15009.

ANNOUNCEMENT — Philadelphia based Delaware Valley Amateur Astronomers now meets 2nd Friday each month at Schuylkill Valley Nature Center on Hagys Mill Rd., Roxborough. For details, write Ed Kaczanowicz, 434 E. Rockland St., Philadelphia, PA 19120.



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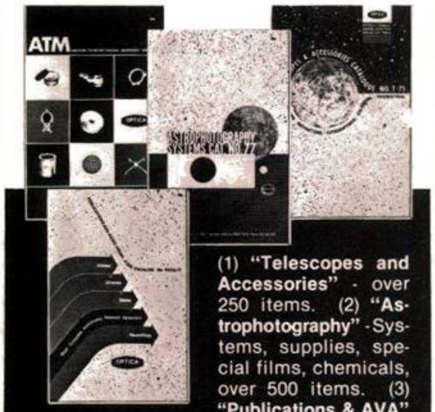

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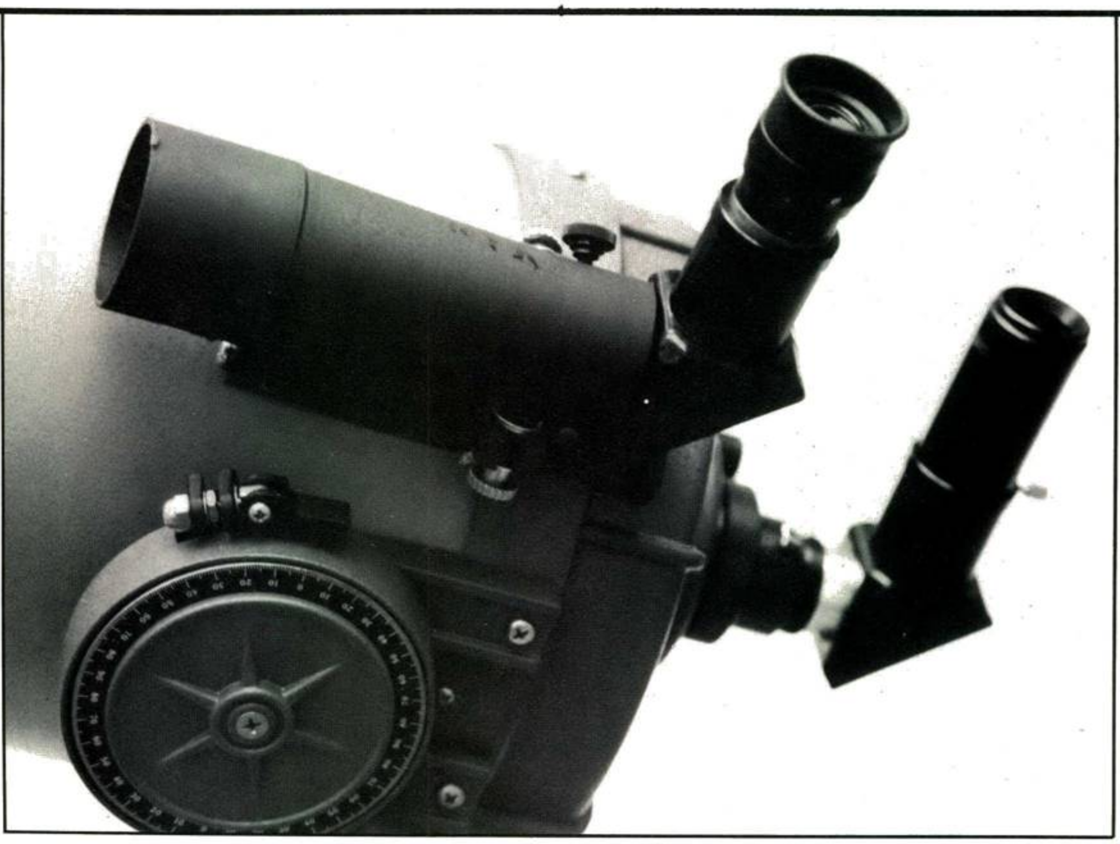

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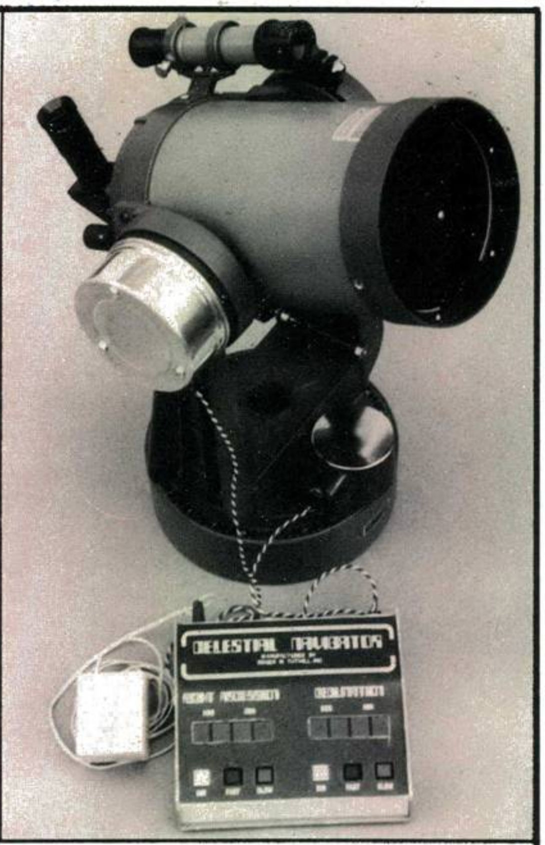

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STAR DOME

JANUARY

by
Dewey Schwartzenburg
and James Mullaney

How can you begin to know the stars? In the first place, put down this magazine and go out to look at them! On second thought, though, take it along and use the Star Dome map on the next page. There are very few among us who can identify *all* the constellations on a given night, so we all can make a few new stellar friends. (When you go out, you won't see much unless you allow 10 or 15 minutes for your eyes to adjust to the darkness, and choose a spot away from artificial lights.)

What's the first thing you'll notice about those lights in the sky? It's probably that they're not all equally bright. Some are so dim you wonder if they're really there at all, for when you look at them directly, they seem to vanish. But when, disappointed, you look away again, you catch them reappearing, as though shy of your direct gaze, hiding when stared at. The actual reason for this is that our eyes are less sensitive to dim light at the center of vision. *Averted vision* is a technique well-known to astronomers, and is used to observe faint detail and dim objects. Instead of looking directly at the object of interest, you look slightly to one side, so that the image falls on a more sensitive part of the retina. Using averted vision, you may be surprised at how many stars are actually visible after all!

Stars could appear at different brightnesses, or magnitudes, for two fairly obvious reasons: They may actually *be* of different brightnesses themselves, or they may lie at different distances from us. Long ago, primitive astronomers debated which was the cause. It was finally agreed that the true reason was that stars are of differing intrinsic brightnesses, since it became an accepted truth that they are all at the same distance from us, attached to the sphere of the outermost "heaven".

Later, when the true depth of space was discovered, many believed that all stars were of the same brightness, or luminosity, and appeared different because of their various distances.

We now know, of course, that *both* theories are true. Some stars, such as Betelgeuse in Orion, appear bright to us because in fact they are relatively bright stars — even though, like Betelgeuse, they may lie at a relatively great distance from us. If our own sun were at the distance of giant Betelgeuse, it would not even be visible to the unaided eye! Other stars are bright because they are relatively close to us, such as Altair (in Cygnus).

What else can we notice about those lights in the sky just by looking at them? Most stars look white in color, but some do not. In fact, all stars have a distinctive color, ranging all the way from blue to red.

Some readers have noted that the star colors portrayed on the Star Dome map each month are not nearly as apparent in the sky as they are on the map. True, there is some exaggeration, but in fact the colors *are* there. Why, then, don't we see more colors in the stars?

The answer has to do with the physical nature of our own visual apparatus. In the human eye, there are two kinds of light receptors: *rods* and *cones*. The rods perceive only light intensity, and no color at all. The cones, on the other hand, are sensitive to colors. But as it turns out, the cones in the retina have to receive a lot of light in order to register colors, while the rods can detect exceedingly low light levels.

This means that as light levels fall, colors seem to fade, becoming less and less distinct until finally we see only in black and white! We are all familiar with this phenomenon, even though we may not notice it. In a dark room, we can often perceive chairs, tables, rugs and so forth, but if the light is very dim, we cannot tell exactly what color they are.

The stars, even the brightest, are actually rather dim, and the cones in our eyes may not register their colors. For the same reason, the striking, dramatic colors depicted in color photographs of celestial objects, such as the Great Nebula in Orion, are not seen through small telescopes. There is just not enough light there to "trigger" the cones. Actually, some individuals may have more color sensitivity than others, so that while one person may see no stellar colors at all, another will be able to see many.

The colors are there in those lights in the sky — why not try to see them some night? Winter is an especially good time, for several relatively bright stars of different colors are well placed in the sky for comparison. Try starting in the south with brilliant white Sirius, the brightest star in the sky, and then move north to blue-white Rigel and deep red Betelgeuse, both in Orion. Farther north, see if you can detect the distinctive colors of Aldebaran in Taurus (orange-red), Capella in Auriga (yellow), and compare Pollux and Castor (orange and white). All are noted on the Star Dome map this month. We recognize our Earthly friends by their appearance, and the colors of stars can help us to know our stellar friends.

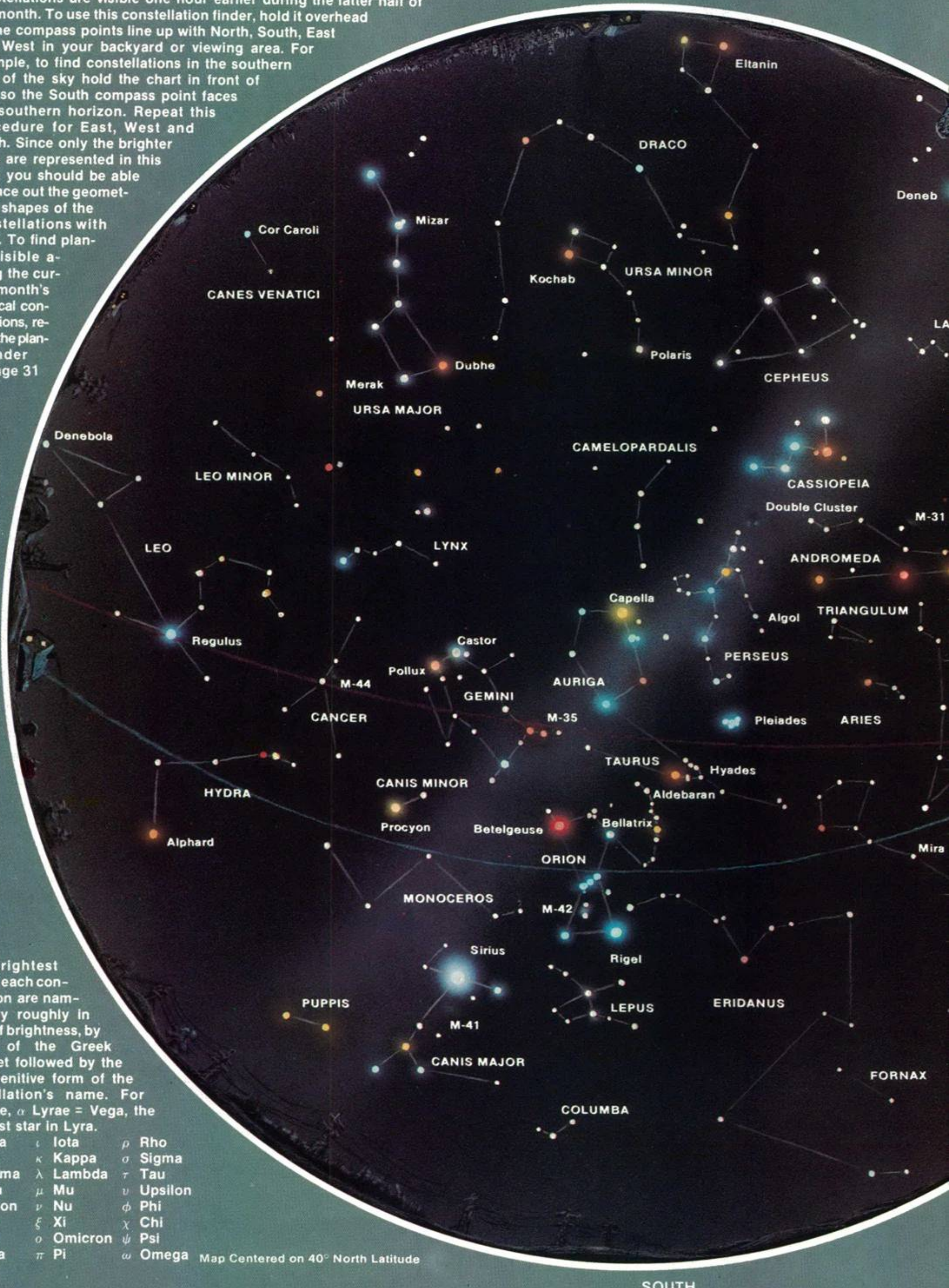
Why are the stars colored? We'll save that for next month!

Close-Up

Taurus Region

"Many a night I saw the Pleiads,
rising thro' the mellow shade,
Glitter like a swarm of fireflies
tangled in a silver braid."

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets visible among the current month's zodiacal constellations, refer to the planet finder on page 31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M-31
LEO
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M-44
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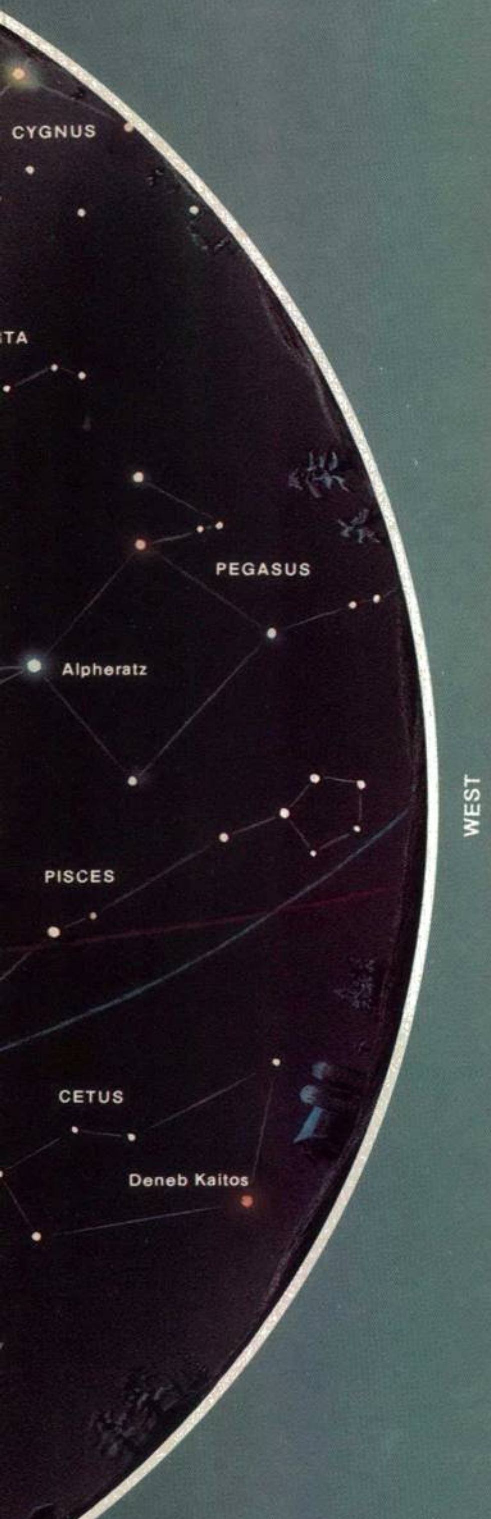
CANCER
M-35
Pleiades
ARIES
TAURUS
Hyades
CANIS MINOR
HYDRA
Aldebaran
Bellatrix
Procyon
Betelgeuse
Alphard
Mira
ORION
MONOCEROS
M-42
Sirius
Rigel
PUPPIS
LEPUS
ERIDANUS
M-41
CANIS MAJOR
FORNAX
COLUMBA

Map Centered on 40° North Latitude

The brightest stars in each constellation are named, very roughly in order of brightness, by letters of the Greek alphabet followed by the Latin genitive form of the constellation's name. For example, α Lyrae = Vega, the brightest star in Lyra.

α	Alpha	ι	Iota	ρ	Rho
β	Beta	κ	Kappa	σ	Sigma
γ	Gamma	λ	Lambda	τ	Tau
δ	Delta	μ	Mu	υ	Upsilon
ϵ	Epsilon	ν	Nu	ϕ	Phi
ζ	Zeta	ξ	Xi	χ	Chi
η	Eta	o	Omicron	ψ	Psi
θ	Theta	π	Pi	ω	Omega



Map by Adolf Schaller

Thus wrote the poet Alfred Lord Tennyson, celebrating the famed beauty of the Pleiades, the seven sisters of the skies. The Pleiades grace the constellation Taurus with their presence.

Taurus the bull swings through our winter skies, ever retreating before the great hunter Orion who pursues his quarry accompanied by his two dogs (Canis Major and Canis Minor). The twins (Gemini) watch the age-long assault as a straying rabbit (Lepus) scurries away from under Orion's feet. Taurus is the center of the action and perhaps, as some tales relate, it is the Pleiades who have occasioned all this furious activity!

Orion is perhaps after them, not Taurus himself, who guards and protects them. They ride on his great shoulder, some say transformed into a flock of doves, as the heroic bull fixes Orion with the orange-red glare of his eye (Aldebaran).

But Taurus shows much more to those with telescopes.

The Pleiades

The bright and dazzling Pleiades star cluster — the finest naked eye jewel box in the heavens — highlights this month's thrilling region. A line extended from Orion's three "belt stars" upward (northwest) on the sky leads us first to Aldebaran and the V-shaped Hyades cluster (see below), and beyond to the Pleiades. Inspiring poets and scientists alike, this cosmic wonder commands attention on clear winter nights.

Also known as M-45, the Pleiades were apparently included by Messier to "round out" the first installment of his famed roster of nebulous looking objects to be avoided by comet hunters. With an apparent angular size of over 100 minutes of arc (nearly four full moon diameters) and an integrated or combined light equal to that of a first magnitude star, it is one of the largest and brightest of all deep sky objects.

How many stars can be seen in the Pleiades without optical aid? On a typical night, six stars are obvious to most observers with occasional glimpses of others. The brightest member is third magnitude Alcyone [Eta (η) Tauri], followed by a clan of fourth and fifth magnitude stars bearing the names Atlas, Merope, Electra, Maia, Taygeta, Calaeno, Pleione and Asterope.

Apparently at some time in the remote past there were seven stars easily visible to the naked eye here, resulting in the cluster's well-known nickname — the Seven Sisters. The legend of the lost Pleiad is nearly universal in all cultures, and may indeed have some basis in fact. The peculiar spectral characteristics of the star Pleione has led some astronomers to speculate that it once shone with temporary brilliance and is the lost sister. Not suprisingly, a vast amount of folklore has arisen over the centuries to account for the missing star.

Keen eyed observers frequently report seeing as many as 14 stars in the Pleiades, and even more are on record. On a dark (moonless) transparent night away from city lights, and with your eyes well dark adapted, search for the cluster with averted vision to see if you can match or even exceed this count. Make a sketch of what you see and check it with binoculars or a photograph — but only after completing the observation, to avoid bias.

Although a real showpiece in binoculars and rich field telescopes, many observers find M-45 a telescopic disappointment due to its great extent — too large to fit in most low power eyepiece fields in its entirety.

Despite its great size, the Pleiades has much to offer the telescope user. More than 100 stars can be seen here in three and four inch scopes, and as many as 500 down to the 14th magnitude are within reach of larger instruments. Webb called attention to "a beautiful triangle of small stars" near Alcyone and mentioned a "remarkable absence of color in the group, except in one minute ruddy star". Both of these features are easily visible in a three inch refractor at 45 power. The rose tinted star lies near the apparent center of the cluster and forms an attractive double star with a blue-white member.

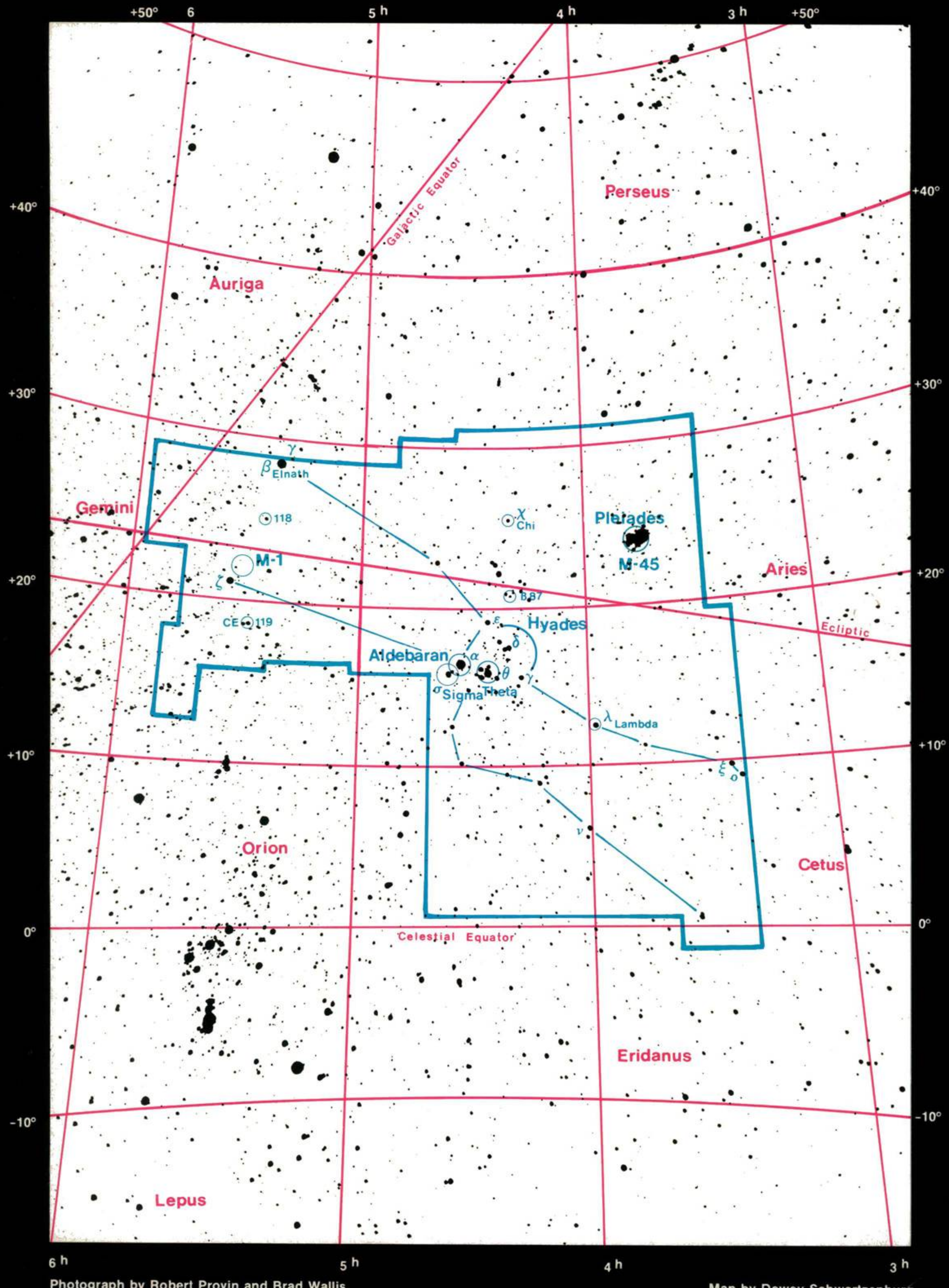
Barns described the glittering units here as "B type giants, blue-white, gold and violet ... involved in far reaching nebulosity." Indeed, most of the stars in the cluster are very young, hot suns having a distinct bluish cast to them. But here and there, minute orange and red ones can be seen — especially in eight inch and larger scopes.

The nebulosity referred to by Barns is often dramatically shown in time exposure photographs of M-45, appearing like mist around mercury vapor street lights on a foggy night. Visually, it's a real challenge even to glimpse. The brightest part of this elusive stellar mist (designated NGC-1435) surrounds the star Merope and was discovered telescopically by Tempel in 1859. Webb found it "a faint extended, somewhat triangular haze, involving, at its north extremity, Merope, the bright star south preceding (southwest) of Alcyone." He further stated he had seen the nebulosity with apertures of less than two inches, but that it was invisible in an 11 inch refractor "possibly from want of contrast in diminished fields".

As with other faint nebulosities like

Epoch 1950 coordinates

TAURUS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Celestial Equator
Eridanus
Lepus

Photograph by Robert Provin and Brad Wallis

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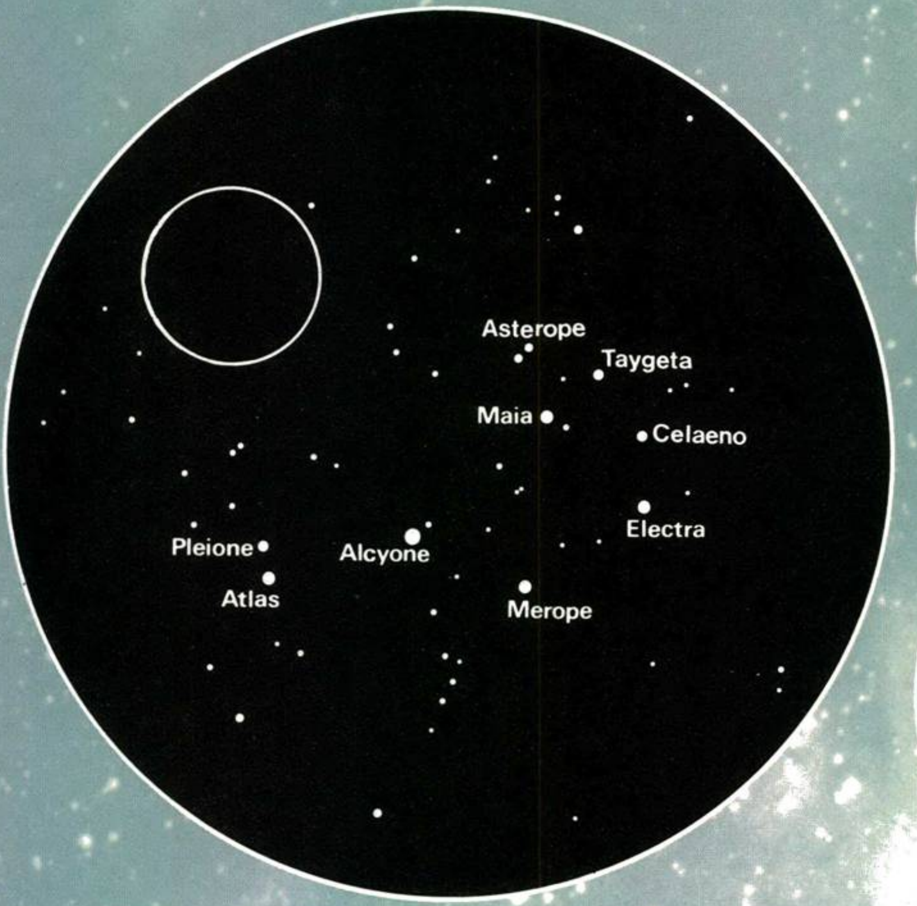
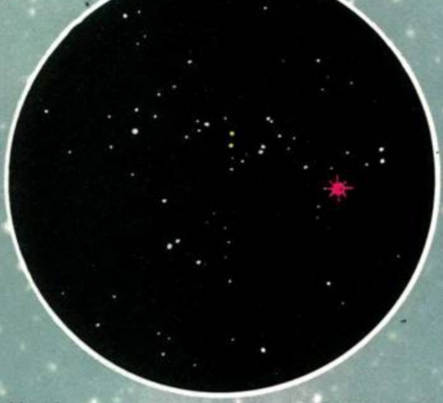
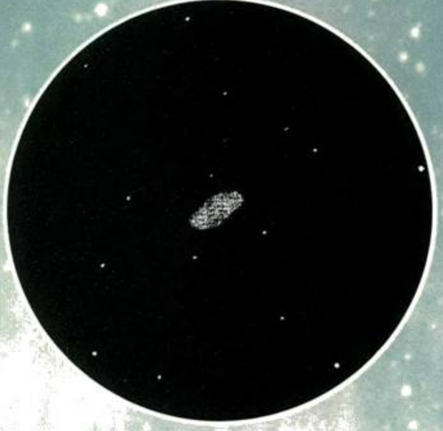


Pleiades (M-45) **Field: 2-1/2 degrees** **4 inch reflector**



Hyades **7x50 binoculars**



Crab nebula (M-1) **40x**

The large drawing shows the principal stars of the beautiful Pleiades cluster. The circle shows the apparent size of the full moon (1/2 degree) for scale. Binoculars or a rich field telescope are best for full appreciation of the richness of this glittering swarm of stars. Drawing by Victor Costanzo. Upper right: The even larger apparent size of the Hyades cluster makes use of binoculars or an RFT essential. The field of view shown here is eight degrees. A broad range of stellar colors is represented, from bright orange-red Aldebaran to shades of blue. Lower right: In small instruments the Crab nebula appears as an oblong patch of silvery gray light, about four by six minutes of arc in size. Large telescopes are necessary to glimpse any of the complex filamentary structure so dramatic in long exposure photographs. Drawings by James Mullaney.

the Horsehead in Orion and the North America in Cygnus, telescope size has less to do with glimpsing the Pleiades nebula than sky conditions and training of your eye. A four inch RFT at 15 to 30 power provides a superb view of the cluster, and on nights of high transparency reveals ghostly wisps of diluted and reflected starlight about several of the brighter members. As you search for it, be aware that the cold winter air promotes frequent fogging of eyepiece lenses from your breath and watery eyes — resulting in sudden and striking nebulosity enveloping all of the Pleiades stars!

Aldebaran

The fiery orange leader of Taurus is the star Aldebaran — a supergiant of spectral class K some 37 million miles in diameter and 100 times more luminous than our sun. At its distance of 68 light-years, it is a stunning sight against the backdrop of the Hyades star cluster.

Aldebaran's vivid reddish-orange tint is a splendid addition to the colorful array of bright winter luminaries. As with heavenly hues in general, different eyes may see this great star differently. Smyth long ago called it "pale rose" in cast and some observers have even suspected actual variations with time from yellow to red. How do you find it?

Aside from its lovely warm color, Aldebaran has several faint stars in the same field with it that offer interesting tests of sky, instrument and observer. Brightest of these is an orange object 114 seconds distant near position angle 35 degrees, variously listed as between 10th and 11th magnitudes. Webb stated that "the minute attendant is a good light test," but also that it had been glimpsed with less than two inches aperture. "My 3.7 inch (refractor) showed it certainly, but not without much attention; 144 (power) suited it better than 80."

Selected Objects — Taurus Region

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.
*M-45 (Pleiades)	○	1.3	100′	03^h44^m	+23°58′
λ (Lambda)	Ӿ★	3.3-4.2	3.9^d	03^h58^m	+12°20′
*Hyades	○	0.8	5.5°	04^h17^m	+15°31′
Burnham 87	★2	6.1,9.1	2″	04^h19^m	+20°42′
χ (Chi)	★2	5.4,8.2	20″	04^h20^m	+25°31′
*θ (Theta) 1-2	★2	3.6,4.0	5.5′	04^h26^m	+15°46′
*Aldebaran	★+	0.9, 10	114″	04^h33^m	+16°25′
*σ (Sigma) 1-2	★2	4.8,5.2	5.5′	04^h36^m	+15°42′
118	★2	5.9,6.6	5″	05^h26^m	+25°07′
CE (=119)	∩★	4.5-5.5	165^d	05^h29^m	+18°34′
*M-1 (Crab)	■	8.8	6′x4′	05^h32^m	+21°59′

*Detailed in Close-Up

○ = Open Cluster Ӿ★ = Eclipsing Variable
★2 = Double Star ★+ = Bright Star
∩★ = Variable Star ■ = Planetary Nebula

The great double star observer Burnham discovered that this tiny star is itself a close pair — magnitudes 11 and 13, with a separation under two seconds. This duo is apparently a physical one, but is being left behind by Aldebaran's space motion and is, therefore, only an optical companion of the great star itself.

We've frequently mentioned in past installments the striking appearance taken on by bright stars like Aldebaran when viewed with a very small aperture at high magnification (a two or three inch at several hundred power, for example). If you own a telescope larger than three inches, try masking it down with a cardboard aperture stop to just an inch or two — on-axis for a refractor, off-axis for a reflector or catadioptric (to avoid their central obstructions). Charged with a high power on a steady night, the diffraction disk and rings produced by objects like Aldebaran are an amazing sight!

The Hyades

The stunning V-shaped splash of glittering stars near Aldebaran is the famed Hyades open cluster — a naked eye spectacle and a real wonder for binoculars and RFT telescopes. Most stargazers are disappointed to learn that Aldebaran is not really a member of this scattered group, but rather is simply projected against it along our line of sight. At a distance of 130 light-years, the Hyades is one of the nearest of all clusters — but it is almost twice as remote as the bright foreground star itself.

Another surprising illusion concerns the shape of the Hyades swarm. Its members are all moving toward the southeast on the sky and appear to be converging at a point near Betelgeuse in Orion. This effect is the result of their actual space motions and simple perspective (much like a meteor shower in reverse). Note that this movement is not toward the tip of the V (marked by the star Gamma Tauri), which the cluster's visual appearance would lead us to believe is the convergence point!

Having an integrated (combined) brightness of a first magnitude star, the Hyades cluster contains at least 40 suns spread over an area of 330 minutes or 5-1/2 degrees in extent — equal to nearly a dozen full moon diameters in the sky. Its actual physical spread in space is some 30 light-years which — combined with its proximity — accounts for its colossal apparent size.

Viewed in binoculars, the Hyades is a marvelous sight; the individual stars seem suspended three-dimensionally against the sky background. Although considered a poor telescopic object by many observers, the cluster has much to offer users of small instruments equipped with a low power, wide field eyepiece. Barns called this area: "A treasure region, including that blazing V-shaped open cluster — the Hyades — 100 blue-white class A suns, golden solar and red Antarean giants." These color differences referred to are obvious in the smallest of telescopes and can even be seen in good binoculars.

In addition to its dazzling array of stellar magnitudes and tints, the Hyades contains an amazing number of apparent double and multiple star combinations in striking proximity. One of the best of these is the pair formed by Theta (θ)-1 and Theta-2 Tauri — a golden duo of fourth magnitude gems some five minutes apart, situated midway along the bottom of the V and obvious to the unaided eye. Another is the easy binocular pair made up of Sigma (σ)-1 and Sigma-2 Tauri. These nearly matched fifth magnitude blue-white suns are also separated by better than five minutes of arc and are located a degree southeast of Aldebaran itself.

The spread in both these wide pairs occurs mainly in declination and is wide enough to split without optical help. They make fine binocular subjects and offer interesting views in three and four inch scopes at 30 to 50 power.

M-1

We conclude our survey of this month's region with one of the best known and most enigmatic of all deep sky subjects. This is M-1, better known as the Crab nebula — the remnant of the celebrated "Chinese Guest Star" or supernova of 1054 A.D.

The nebula itself was apparently first noticed by Bevis in 1731, and its accidental rediscovery by Messier while following a comet in 1758 led to the compilation of his well-known catalog of clusters and nebulae. His description of this first entry reads as follows: "A whitish light, elongated like the flame of a taper."

To find the Crab nebula, follow the line formed by the bottom row of stars in the Hyades eastward some 15 degrees (or one hour of right ascension) to the third magnitude star, Zeta (ζ) Tauri. Just a degree to the northwest of this star lies the pale glow of M-1. Although visible in a good finder or binoculars on a dark night, it will require a low power eyepiece on the telescope itself to be picked up most nights. Even then it is easily passed over in sweeping until once seen. Our drawing through a four inch scope at 40 power shows what you can expect to see.

At visual magnitude 8.8 and measuring 6 by 4 minutes in size, M-1 is obvious even in a 2.4 inch refractor at 30 power, and its outline is definite in a six inch reflector at 50 power. The serrated edges and filaments that are seen in photographs of this object can be glimpsed with averted vision on a dark steady night in eight inch and larger instruments.

Webb described M-1 as "oblong and pale" and mentioned that it looked granular in his 9.3 inch reflector. Barns commented on the view through his 10 inch reflector: "Famous 'Crab nebula' of Lord Rosse (the analogy presupposed a strong Irish imagination), fairly defined tho' pale." Pickering included this object in his roster of the sky's 60 finest showpieces compiled with an 11 inch refractor, calling it a "a somewhat egg shaped body".

Lord Rosse named M-1 from its visual appearance in his great 72 inch homemade metal mirrored reflecting telescope, and thought it was resolvable into stars (Webb's granular aspect?). This was at a time when all nebulae were thought to be composed of unresolved stars. The object does indeed look crablike in a modern 10 or 12 inch reflector on a good night. It also looks much more like a typical diffuse nebula than a planetary, which as we've seen in the past, generally have very small bluish-green disks.

The Crab nebula is composed of incandescent gases expanding outward at enormous velocities in all directions from the site of the original supernova outburst. Viewed from our vantage point some 6,000 light-years distant, the explosion actually occurred 60 centuries before it was first seen on Earth, due to the travel time for its light to reach us. Likewise, we are seeing the nebular remains as they appeared that long ago and not in their present state.

Near the apparent center of the Crab nebula lies perhaps the best known and most studied example of a pulsar in the sky. Thought to be the neutron star remains of the supernova itself, it pulses its light and other energy output at the incredible rate of 30 times a second. So rapid is this variation that the human eye and ordinary photographs show the object as constant in brightness (much the same situation as with an ordinary television picture). High speed photographic and television image intensification devices, however, clearly reveal this bizarre object from the stellar graveyard blinking on and off.

As we watch the Crab nebula, we are witnessing the death of a star — one that was perhaps another civilization's life-giving sun. One of the grandest thoughts concerning this ultimate fate of all living things is that inscribed on the crypt of famed lens maker John Brashear and his devoted wife: "We have loved the stars too fondly to be fearful of the night."

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